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SAFE SOUND EXPOSURE IN THE FETUS AND PRETERM INFANT

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Abstract

Exposure to sound can have both beneficial and harmful effects on the developing fetus and preterm infant. Although recommendations for safe exposure to sound have existed for more than three decades, reports indicate that these recommendations are not being followed.

Recommendations are made to promote attention to the problem of unsafe exposure to sound in early development, and a multidisciplinary team, including representatives from disciplines beyond medicine and nursing, must re-address safe exposure.

Keywords

Fetus; Preterm Infant; Sound; Neonatal Intensive Care Unit

Exposure to sound is a necessary and consistent form of sensory stimulation in the developing fetus and preterm infant. As such, it is a common component of interventions and research directed toward the care of the fetus and preterm infant. Intense and sustained sound, however, has serious implications for the developing vasculature and brain of the fetus and premature infant with resultant physiological and behavioral effects (Chang & Michael, 2003; Darcy, Hancock, & Ware, 2000; Williams, Sanderson, Lai, Selwyn, & Lasky, 2009).

The fetus has a developmental advantage over the preterm infant because the tissues of the maternal abdomen and uterus filter out most high-frequency sounds and attenuate or lessen decibel (dB) levels by as much as 20 to 35 dB (Gerhardt & Abrams, 2000; Richards, Frentzen, Gerhardt, McCann, & Abrams, 1992). The normal frequency range that can be heard by an adult is between 20 and 20,000 Hertz (Hz) (Gray, 2000); however, the younger fetus (up to 27 weeks gestation) hears predominantly lower frequencies (below 500 Hz) and probably cannot detect frequencies above 500 Hz until 29 weeks due to filtering by the maternal tissues (Gerhardt & Abrams, 2000).

This normal developmental filtration and padding of sound by the uterus can therefore be significantly compromised by intense and sustained sound presented at either low or high-frequencies and elevated dB levels. For example, vibroacoustic stimulation (a combination

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of low-frequency sound and vibration) applied directly to the maternal abdomen can produce an atypical response or increase in fetal heart rate and movement not normally seen (Gagnon, Hunse, Carmichael, Fellows, & Patrick, 1986). Studies in humans and nonhumans have demonstrated that exposure to intense and sustained sounds outside the dB and frequency range normally heard by the fetus is harmful and may be related to hearing deficits, chromosomal abnormalities, elevated cortisol levels, decreased lactogen levels, and abnormal social behavior following birth (National Research Council; Committee on Hearing, Bioacoustics, and Biomechanics; Assembly of Behavioral and Social Sciences, 1982; Clarke & Schneider, 1993; Clarke, Wittwer, Abbott, & Schneider, 1994; Douek, Dodson, Bannister, Ashcroft, & Humphries, 1976; Jones & Tauscher, 1978; Geber, 1966; Lalande, Hetu, & Lambert, 1986; Lenoir & Pujol, 1980; Murata, Takigawa, & Sakamoto, 1993; Weinstock, Matlina, Maor, Rosen, & McEwen, 1992; Zhang, Cai, & Lee, 1992). However, some studies have been unable to be replicated or lacked an adequate control group (Edmonds, Layde, & Erickson, 1979; Hartikainen-Sorri, Kirkinen, Sorri, Anttonen, & Tuimala, 1991; Kurppa, Rantala, Nurminen, Holmberg, & Starck, 1989). Once identified in the newborn, hearing deficits have been largely located in the inner and outer hair cells within the cochlea, a region of the ear most affected by low-frequency sound (<250 Hz) (Gerhardt & Abrams, 2000).

Although the maternal abdomen and uterus filter out most high-frequency sounds and lessen dB levels, preterm infants in the neonatal intensive care unit (NICU) have no such protection. While in the NICU, the preterm infant is fully exposed to a broad range of sound frequencies (high and low) at dB levels that may be unsafe. Elevated levels of sound generated by operational (staff/equipment generated) or structural (building-generated) sources in the NICU (Evans & Philbin, 2000; Philbin, 2004; Philbin & Gray, 2002) have been shown to interfere with an infant's sleep and to have negative effects on vital signs and oxygen saturation (Bremmer, Byers, & Keihl, 2003; Lai & Bearer, 2008; Salavitarab et al., 2010). As with the fetus, excessive sound levels may seriously impact preterm infant development, including cochlear damage, weakening of the vessel walls in the cerebral vasculature, and subsequent intracranial bleeding (Darcy, Hancock, & Ware, 2000; Graven, 2000). In addition, the increased number of speech and language delays seen in preterm infants may be related to unsafe exposure to sound in the NICU (Brown, 2009). While substantially established in nonhumans (Lickliter, 2000), it may be that excessive sound within the NICU masks meaningful sounds for the human premature infant, such as the parent's voice, resulting in delayed development of interactions between the infant and parent (Kuhl & Melzoff, 1984).

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Current Recommendations for Exposure to Sound

As early as the 1970's and later in 1997, the American Academy of Pediatrics Committee on Environmental Health made recommendations to address the effects of elevated sound exposure in NICUs (American Academy of Pediatrics, 1974; 1997). These were later updated by a multidisciplinary group of clinicians and researchers (Sound Study Group) who broadened the recommendations to include the fetus (Graven, 2000). At present, these guidelines are referred to internationally in the care of fetuses and infants (Antonucci, Porcella, & Famos, 2009; Brown, 2009; Chen & Chang, 2001; Chen, Chen, Wu, Huang, & Hsu, 2009; Ramesh et al., 2009).

The Sound Study Group's recommendations for the fetus were as follows: 1) women should avoid prolonged exposure to low-frequency sound levels (<250 Hz) above 65 dB during pregnancy; 2) sound devices, including earphones, should not be directly placed on a pregnant woman's abdomen; 3) programs to supplement the fetal auditory experience (e.g.,

such as playing music) are not recommended since the voice of the mother and normal sounds of the mother's body are sufficient for normal fetal auditory development (Graven, 2000).

The Sound Study Group recommendations included the following for preterm infants: 1) the hourly Leq should not exceed 50 dB; 2) the hourly L_{10} should not exceed 55 dB; 3) the 1 s L_{max} should not exceed 70 dB in the NICU; 4) earphones and other devices attached to the infant's ears for sound transmission should not be used at any time (Graven, 2000). The recommendations for maximum dB levels were subsequently reviewed by members of the Sound Study Group (Philbin, Robertson, & Hall, 2008), and no additional recommendations were made (see Table 1).

Current Research on Exposure to Sound in Clinical Settings

Nearly a decade since the Sound Study Group's recommendations, in the United States and elsewhere, clinicians and researchers continue to engage in practices that subject fetuses and preterm infants to potentially harmful sound levels (Lai & Bearer, 2008; Salavitarab et al., 2010;). In the United States, recent reports of sound levels in NICUs have ranged from an Leq of 50–89.5 dBA with peaks (or L_{max}) of 105 dBA (Darcy, Hancoc, & Ware, 2008; Lasky & Williams, 2009; Matook, Sullivan, Salisbury, Miller, & Lester, 2010; Williams, van Drongelen, & Lasky, 2007). These sound levels have also been reported as occurring for as much as 70% of the time (Williams et al.).

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These conditions are not specific to the US. For example, in Taiwan the hourly Leq within two locations in an NICU averaged 61.4 dBA and 62 dBA with 86% of the peaks or L_{max} ranging from 65–74 dBA (Chang, Lin & Lin, 2001). Average NICU dB levels in India were reported to range from 61.2 dBA to 68.0 dBA in non-ventilator versus ventilator-assisted rooms, respectively (Ramesh et al., 2009).

Recent studies conducted outside the US assessed fetal well-being using methods that were inconsistent with the Sound Study Group's recommendations (Chittacharoen, Chaitum, Suthutvoravut, & Herabutya, 2000; Phattanchindakun, Boonyagulsrirung, & Chanpraphaph, 2010; Tongprasert, Jinpala, Srisupandit, & Tongsong, 2006). Contrary to the recommendation that sound devices should not be applied to a pregnant woman's abdomen, researchers continued to place devices, through which either sound or a combination of sound and vibration were played, directly on the maternal abdomen (Chittacharoen et al.; Phattanchindakun et al.; Tongprasert et al.). The ethics of these methods are questionable (Tongprasert et al.). Standards of care, which do not use devices placed directly on the maternal abdomen to produce sound, are equally as effective in detecting poor fetal outcomes (Phattanchindakun et al.). Thus, use of such methods in research and in clinical practice should be critically examined.

Future Recommendations

Why unsafe practices continue in the presence of clear evidence that elevated and/or sustained sound levels is unhealthy for the developing fetus and preterm infant is, no doubt, multifaceted. Many NICUs were constructed prior to the Sound Study Group's recommendations (Graven, 2000) and are thus facing high costs for structural modifications to reduce elevated and/or sustained exposure to sound. In addition, while successful education programs and studies identifying ways to reduce unhealthy exposure to sound have been published (Chang, Pan, Chang, & Lin, 2006; Laudert et al., 2007; Philbin, 2004; Philbin & Gray, 2002), changing operational factors (e.g., NICU staff behavior, use of

alarms, and research practices) requires continued education and vigilance to maintain lasting change.

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Research recommendations

It has been a decade since a multidisciplinary team (Sound Study Group) met to address the problem of elevated and/or sustained exposure to sound in early development (Graven, 2000). The next logical step must be to widen the disciplines involved in making recommendations. In addition to the inclusion of medicine and nursing, disciplines capable of addressing technological issues (biomedical engineering), behavioral issue and those in a position to make policy changes are needed.

Engineers are needed with the skill to develop remote alert systems in which the primary nurse and/or team members can stay informed of their patients' conditions using individualized ear pieces that can be heard by the nurse and/or team but not the infants. Psychologists are needed to evaluate how we maintain behavior change beyond the immediate training sessions. Partnerships such as this are necessary to ensure safe and lasting approaches to the problem of elevated sound levels.

Further, many journals are now international. Will it be necessary to ask editorial boards to provide closer safety evaluations of studies involving the fetus and preterm infant? If the likelihood of subsequent publication (whether in the United States or internationally) is reduced by participating journals, the conduct of such studies should diminish.

Practice recommendations

Providing safe prenatal and early neonatal care is not just the responsibility of the family and health care providers. It is also that of the policy makers within each health care system responsible for providing care during this vulnerable time in early development. Technology is now available and in some cases already in place to strategically monitor and alert staff when sound levels exceed established policies. However, these policies must be enforced realistically. If a lower decibel level is the goal of an existing policy, how will it be enforced if no other alternative to alarms produced by cardiorespiratory monitors, pulse oximeters, and ventilators are provided?

Policy makers must also be attentive to the literature. Use of sound attenuating devices, keeping staff away from bedsides during shift reports and other strategies have been suggested. Where there is evidence to safely and effectively address the issue of elevated sound levels, it is the ethical obligation of those involved in their care to keep abreast of new and innovative ideas to address this dilemma.

Summary

As a discipline composed of clinicians and researchers, nursing can take the lead in addressing these issues. Nursing is ideally situated to provide knowledge obtained from the bedside in conjunction with nurse researchers to apply evidence within the clinical setting to maintain safe sound levels for the developing fetus and preterm infant.

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Table 1

Measurement of Sound

Measure	Description
Leq	Equivalent steady noise level that would contain the same noise energy as a time- varying noise levels across the same sampling period.
L ₁₀	Measure of the decibel level exceeded for 10 percent of the hour.
L _{max}	Highest decibel level measured for a duration of at least 1/20 th of a second during the hour.

Hirschorn, 1989; Beranek, 1988