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Inadvertent Noise in Neonatal Intensive Care Unit and its Impact on Prematurely Born Infants

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Abstract

Noise leads to many adverse health effects - from short-term disturbances of homeostasis, to long-term changes in the central nervous system, which are responsible for abnormal cognitive development and limitation of language skills. Medical care is primary source of noise in intensive care units. Many of noise-generating factors could have been eliminated. In order to reduce bad habits and enforce correct practices, an internal recommendation is necessary to implement. The protective intrauterine environment enables gradual maturation of the fetal hearing organ, in particular very sensitive receptor cells in the cochlea. Preterm delivery significantly disturbs the normal development of the child's auditory perception. Stimulation with sound stimuli like those experienced during the fetal period, positively influences the proper development of the nervous system of premature babies and protects against harmful effects of hospital environment noise.

Abbreviations: NICUs: Neonatal Intensive Care Units; TOS: The Original Sound; DBA: Decibels adjusted; CPAP: Continuous Positive Airway Pressure; HFNC: High Flow Nasal Cannulae

Introduction

The Intrauterine Sound Environment

Development of the hearing organ is a complicated and long-lasting process that begins in fetal life. Acoustic stimuli that child receives intrauterine are significantly different from those generated in the external environment. Prenatal sound exposure stimulates the proper development of the nervous system and the sense of hearing. Protective intrauterine environment allows the gradual maturation of the hearing. The child begins his auditory experience with a continuous, rhythmic mixture of sounds - mother's voice, heart tones, respiratory murmurs, intestinal peristalsis. Central and peripheral part of the hearing organ, receives and converts sound waves, after the completion of the 5th month of pregnancy [1]. At the same time, myelination of the auditory neural path begins [2,3]. In the fetal period, not only reception, but also differentiation of sounds and auditory memory are formed [4]. Sounds from the extracorporeal environment are conducting by the mother's tissue, amniotic fluid and then the child's bone system, reaching the hearing organ of the fetus, however they are significantly suppressed. Sound intensity in the uterus rarely exceeds 30 dB [5]. The sounds of conversations are received by the organ of the fetal hearing in about 30% of the original intensity, while the intonation and timbre of the voice are perfectly conducted through the amniotic fluid [4,6]. Prenatal sound exposure contributes to the formation of nerve pathways in the fetal brain, essential for the development of hearing and speech after birth [7,8]. Fetal response to sounds at specific frequencies (100Hz, 250Hz, 500Hz, 1000Hz, 3000Hz) was tested [9]. The first noticeable response to the sound was observed in the 19th week of pregnancy. Initially, the fetuses reacted only to low frequencies of 100-250Hz. Reaction to the higher frequency of 1000Hz, and 3000Hz appeared respectively in 33 and 35 weeks gestation. The ability to perceive higher frequency auditory stimuli increases with the age of the fetus. Sensitivity to sound with lower frequencies may have to promote the sounds of human speech, which fall in the range of 500-3000Hz.

The Clinical Significance of a Positive Sound's Stimulation in NICU

Preterm delivery significantly disturbs the proper development of the child's auditory perception. The protective role is played by sounds familiar from intrauterine life - mainly the voice and heartbeat of the mother. The ability to recognize the mother's voice indicates the importance of this function, especially when considering premature babies. Researchers studying brain activity induced by the mother's voice, heard by newborn immediately after birth, showed activation in the posterior temporal regions of the left

hemisphere mainly, and in areas related to emotion-amygdala and periorbital cortex [10]. Activation in speech-related cortical regions was also found, while the foreign voice activated undetermined areas in the brain [11]. The influence of the mother's voice stimulation on the development of the cerebral cortex, newborns born between 25 and 32 weeks of pregnancy, hospitalized in neonatal intensive care units (NICUs), was examined. It has been shown that acoustic stimulation with the mother's voice lasting 45 minutes three times a day was enough for proper development of the cerebral cortex [12]. Neonates exposed to the mother's voice sounds, had a thicker layer of the cerebral cortex in the region responsible for auditory stimulation, compared with premature infants in the control group exposed only to the sounds of the hospital environment. Based on ultrasound examinations, it was found that the cerebral cortex of newborns listening to the voice and mother's heartbeat was broader on the right than the left side. In addition, many brain fissures have been shown 1-2 weeks earlier on the right side, including temporal furrows. During speech processing in the brain of adults there is functional lateralization, which concerns the left hemisphere.

However, the brain of premature infants does not show hemispheric speech direction, thus auditory neuroplasticity occurs on both sides [13,14]. Positive auditory experiences are extremely important for the recovery and development of premature newborns. Stimulation with sounds like those experienced during the fetal period, protects against the adverse effects of acoustic stimuli present in the hospital environment. To evaluate the effect of the exposure to "The Original Sound" (TOS), an original track composed of different sounds such as fetal heartbeat, breathing, blood flow, and ambience sounds, specifically created, on physiological stability of preterm infants. The study had provided preliminary evidence for short-term improvements in the physiological stability of preterm infants using TOS. Preterm newborns responded to maternal sounds with decreased heart rate throughout the first month of life. Maternal sounds improve autonomic stability and provide a more relaxing environment for this population of newborns. Further studies are needed to determine the therapeutic implications of this non-pharmacological approach for optimizing care practices and developmental outcomes [15,16]. Positive sound stimulation allows to achieve [17,18]

a) Normalization of heart rate and pulse release,

b) Reduction of the number of breaths,

c) Deeper and longer sleep,

d) Reduction of energy at rest,

e) Increase in oxygen saturation of arterial blood,

f) Improvement of the sucking reflex and

g) Greater weight gain.

The Implication of Noise on Developmental Disorders and Recovery of Premature Infants

Noise, an environmental stimulus, is especially important in the neurobehavioral development of newborns and brain development of infants at high risk. Conditions in the NICUs, may cause certain sensory stimuli that are not appropriate for the development of newborns, especially preterm infants. High-risk infants will often spend weeks to months in the NICU, where noise levels can easily reach 120 decibels adjusted (dBA) on a regular and sometimes consistent basis [19]. Hearing impairment is diagnosed in 2% to 10% of preterm infants versus 0.1% of the general pediatric population [20]. The receptor cells in the cochlea are particularly sensitive and susceptible to noise-related damage [21]. The type of damage depends on the frequency, intensity, duration of sound and the maturity of the child [22]. In premature infants exposed to the loud NICU environment, there are neuropathological changes in the central nervous system, such as: regional brain volume reduction, white matter microstructure abnormalities, as well as abnormal cognitive development and reduction of language skills [23-27]. Exposure to noise is the cause of many disorders of homeostasis in the newborn, especially born prematurely. The subcortical structures of the brain and the sympathetic autonomic system are activated, which triggers the hormonal and somatic reaction of the body.

Adrenal hormone secretion, glucose levels and energy consumption increase. Apnea decreases saturation and intraventricular hemorrhage may appear. Muscle tension increases. Peristaltic bowel movements intensify. The function of the immune system is compromised [28-31]. The noise causes sleep disturbances and disturbs the circadian rhythm of the child. Long-lasting noise causes disturbances of children's mental development [24,25,27]. The researchers also emphasize the increased risk of hearing loss in newborns of mothers who were exposed to high-intensity sounds during pregnancy. Likewise, pregnant women should not be exposed to high levels of noise at work [32]. The United States Environmental Protection Agency recommends that the noise level in the hospital should not exceed 45 dB during the day and 35 dB at night. Sound intensity values in intensive care units recommended by the American Academy of Pediatrics are 45 dB, while British standards suggest a maximum noise level of 60 dB [22,33].

The sound reduction management in Neonatal Intensive Care Unit.

Medical care is the main source of noise in intensive care units (Table 1). Studies have shown that the average noise level in the neonatal unit was approximately 62dB. The noise above 59dB was recorded by 70% of the measurement time. During the 24-hour test, noise peak (sounds above 65dB) took place almost 5000 times, and 90% was dependent on people [34]. The ventilation method also affects the noise level. Continuous positive airway pressure (CPAP), used for respiratory support of preterm neonates, is known to be associated with prolonged exposure to high levels of noise. Another means by which noise can reach the ears of neonates is via the Eustachian tube. This mode of transmission would be further facilitated by the fact that CPAP produces a positive pressure encouraging the opening of the Eustachian tube. As the flow rates are increased, noise intensities in the post-nasal space also rise.

For example, at a flow rate of 10 liters/min, a mean noise level of 100.3 dB is generated [35]. However, there is no increase in the hearing loss in preterm neonates treated with CPAP, as compared to mechanical ventilation, despite being exposed to higher environmental noise generated by the CPAP [36]. High flow nasal cannulae (HFNC) are an increasingly popular alternative to CPAP for treating preterm infants. At the gas flows studied, HFNC are not noisier than CPAP for preterm infants [37].

Table 1: Sources of noise in NICU. [28,34-36,39,40].

Noise-Generating Factors	Sound Intensity in Decibels [Db]
Dependent on Medical Staff	
Dynamic closing of the incubator windows	85
Putting the bottle on the incubator from a height of 10cm	90
Running water during hand wash	75
Finger tapping in the incubator	80
Dynamic closing of the drawer	89
Conversation near the incubator	55-65
Cough near the incubator	70-75
Laughter near the incubator	55-85
Scream at a distance of 10m from the incubator	85-90
Dependent on Medical Devices	
Incubator on	44-50
Disconnecting medical gases from the socket	102
The sough of the activated medical suction device	65
Conventional ventilation	38-56
Continuous positive airways pressure 5 l/min.	86
Continuous positive airways pressure 10 l/min.	100
High flow nasal cannulae	80-95
Alarm peaks	85-100

The devices, that constantly monitor the sound intensity, help to reduce the noise level. Sensors have a built-in microphone and an acoustic wave amplifier that amplifies ambient sounds, adding acoustic energy and converting to electrical potential. The potential, reaching the appropriate threshold level, triggers a red light alarm emitted by the LED. The data clearly indicate, that the use of sound sensors with alarm, has a positive effect on reducing the noise level in NICU. The 24-hour sound intensity decreased, and the number of noise peaks > 65dB decreased by about 70% [34]. New construction and technological solutions are still being sought, enabling the greatest reduction of noise, to which newborns in incubators are exposed. The absorbing panel, placed in the incubator cover, silences the noise from the outside and the inside of the incubator and prevents its amplification, keeping the intensity of sounds within the acceptable limits [38]. The influence of using earmuffs on premature babies on their physiological and motor reactions was also examined. Isolated premature infants had a higher saturation of arterial blood, the lower the value of heart rate, slower and steady breathing and less violent and less frequent spontaneous movements [39-40]. It is difficult to limit the intensity and frequency of sound emitted by all devices necessary for neonatal therapy. The focus should be on noise-generating factors that can be eliminated. In summary, protection against noise consists of:

a) Continuous monitoring of the sound level by means of professional devices,

b) Removing noisy equipment from the incubator environment (radio, TV, mobile phones),

c) Using covers for incubators, laying premature babies in nests made of soft and wrapping materials,

d) Implementing internal recommendations, reducing bad habits and enforcing correct practices: avoiding placing objects on the incubator and knocking on the incubator cover, careful closing of the incubator's door, limiting conversations near infants to the necessary minimum, conducting discussions in separated rooms, using appropriate shoes with soft soles, delicate opening of drawers and disposable packaging, gently disconnecting plugs from the sockets,

e) Lowering the volume of alarms and immediate reaction to alarm signaling.

Conclusion

Noise leads to many adverse health effects - from short-term disturbances of homeostasis, to long-term abnormal development of the central nervous system. Reducing noise levels in the NICU can improve the physiologic stability of preterm neonates and

therefore enlarge a potential for infant brain development. Preterm infants, hospitalized in NICUs, should be stimulated with positive sound stimuli, that affect the proper development and recovery.

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