Longitudinal Recording Revealed Preterm Infants' Acoustic Experiences Per Individual in Clinical Environments

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Abstract: To reveal how much clinical treatment longitudinally affects a patient has been observed as the key to select the following care strategy. This paper reports our technological development to realize this longitudinal observation quantitatively of preterm infants' experiences in the clinical environments by constantly recording and analyzing the sounds emerged in an incubator of a neonatal intensive care unit (NICU). The data were acquired by a sound level meter (sample rate 24 kHz) and were performed frequency analysis by our customizing application on Matlab. The present results are from one clinical case utilizing the longitudinal detector system. Auditory identification with frequency analysis visualized the environmental sounds whose frequency distribution is over 500 Hz, seemed intermittently repeated like circadian waveforms of clinical intervention sounds, such as ventilation cares during not daytime but night. This longitudinally automatic recording and analyzing technology may contribute to select chronically therapeutic intervention, supposedly in the susceptible periods for earlier neuronal development.

Key-Words: *Longitudinal Recording, Preterm Infants, NICU, Ventilation Care Sounds, Clinical Treatment*

1. Introduction

Every year, an estimated 15 million babies are born preterm (before 37 completed weeks of gestation) or low birth weight (less than 2500 grams), many survivors face a lifetime of disability, including learning disabilities and visual and hearing problems [1]. And, the advances in neonatal medical treatment and nursing have significantly reduced the mortality rate from 55.3% (1980) to 15.2% (2000) in extremely low birth weight infants (500 g to 999 g) and from 20.7% (1980) to 3.8% (2000) in very low birth weight infants in Japan [2-3].

Several studies have shown that environments influenced the neonates' function to self-regulate [3-5]. It was, in some case, reported that sudden, jarring, or transient sounds might cause unstable physiological states, resulting in tachycardia, bradycardia, increased intracranial pressure, and hypoxia [4].

Our previous studies described the essential bio-mechanisms of susceptible period learning for the neuronal development in specific infantile terms [6-9]. The neuronal circuit formation in the earlier stages crucially affect physiological and psychological function including social adaptation in the latter stages. The critical period learning systems have been addressed the regulation mechanisms by complex interaction between genetic and environmental factors. In particular, it was well-studied that sensory environments significantly impact the basic neuronal developments [6,7,9].

In the current study, we firstly focused on featuring auditory environments surrounding a preterm infant

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preliminarily by our longitudinal detector to measure and analyze the sounds in a NICU incubator. We further explored to infer the patient's clinical condition in the circadian rhythm visualization analysis. As our analyzing strategy, we hypothesized the difference of acoustic environment for preterm infants from fetuses at high-frequency sounds over 500Hz, which was previously reported uterine structures supposedly protect the fetus from the high-frequency environmental sounds [10].

2. Method

We complied with the approved contents by Saitama Medical University Hospital Institutional Review Board (IRB) Committee. To find any circadian oscillation events in the preterm infants' clinical environment, we set up the system that could longitudinally record and analyze the sounds for several days or a few weeks at an incubator (Figure 1).

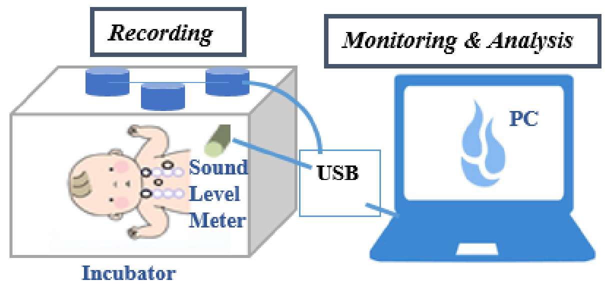

Figure 1 The system of the sounds recording and analyzing longitudinally at an incubator in NICU. It was observed from November 13th to 21th in year 2016.

2.1 Participant

We randomly selected a participant from extremely preterm patients (less than 28 weeks). The birth information was as follows; weight: 1089g, height: 35.4cm, and gestational week-age: 27 weeks.

2.2 Incubator sounds measuring

The sound data were measured after the consent was obtained from the parents. All the data were acquired by a sound level meter (sample rate 24 kHz), which is a non-contact and non-invasive for the infant in the closed incubator.

2.3 Sound data analysis

The sound data were performed automatic frequency analysis by Matlab customized application. Based on signals time-frequency analysis, we analyzed the sound frequency, over 500Hz estimated as the wind exposing to preterm infant out of the uterine [10].

2.3.1 Sound data prepossessing

The sound over 500Hz was processed by the 6th-order Butterworth high-pass filter. Then the sound signals are normalized to scale of [-1, 1] is expressed as:

$$x(i) = \frac{x_m(i)}{|\max(x_m(i))|} \quad (1)$$

Where $x(i)$ is the recorded signal, $x_m(i)$ is the filtered signal.

2.3.2 Quantitative evaluation index extraction

In order to detect the sound presence and duration time in the longitudinal period, we firstly defined the minimum threshold line which was calculated the average of the signal amplitude. Secondly, although the high-pass filter had been already used to eliminate the signals under 500Hz, there were still weak interference noises existed, thus, we improved them by averaging the sounds duration time and collecting over the baseline. To ensure the accuracy of sound detection, we heard the sounds to check them by our ears.

3. Results

The sounds presence time and duration in the incubator, that frequency over 500Hz, were visualized in a 48 hours' double-plot figure whose horizontal and vertical axes show the time of 48 hours as two serial days and the date of measuring day, respectively, in Figure 2. The color displays the index intensity according to the color scale defined 0 to 1000 shown beside the figure. Upon the hearing confirmation, we can find the continued pop-up parts, marked by red '*', which are the ventilation care sounds for respiratory support. These results clearly visualized the duration of respiratory intervention performed November 13th to 14th, 16th to 17th, 18th to 19th, and 21th.

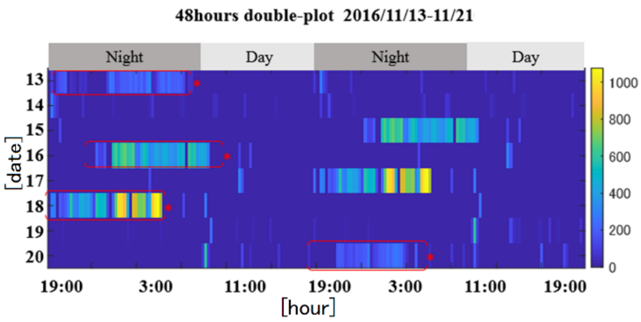

Figure 2. The high-frequency sounds duration in the preterm infant's incubator. Red '*'marked duration: the ventilation respiratory support.

4. Discussion

By our recording and analyzing system with the circadian analytic view, we aimed to quantitatively visualize how a preterm infant experienced the incubator life longitudinally with the clinical intervention. The system revealed that the focused high-frequency sound over 500 Hz that is supposedly eliminated in utero normally [9], emerged from the necessary clinical intervention equipment for respiratory support at night. The sounds intensity was figured out differently per pop-up duration, which might describe the infant's condition. This preliminary study suggests us requirement to follow the sound exposure influence to the infant's neuronal development. Since either circadian rhythms or sensory cognition has been reported as the key notes for development [6-9], we would furthermore study biological sounds such as an infant and care-givers' activities and voices with the environmental sounds by this longitudinal life-observation system.

5. Conclusions

Our longitudinal sounds detector system and acoustic identification with frequency analysis visualized the environmental sounds in incubator, particularly frequency distribution over 500 Hz, were represented repeated like circadian waveforms intermittently because of required clinical intervention sounds. Our automatic recording and analysis method showed how the individual experienced acoustic environment in the earlier neuro-developmental period quantitatively. This technology may contribute to select chronically therapeutic intervention for developmental disorders.

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