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Assessment of environmental noise and its effect on neonates in a Neonatal Intensive Care Unit

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ABSTRACT

A method for analyzing the influence of noise on newborns is proposed. The method consists of defining three different types of time interval (quiet, noisy and nursing) and, for each period, environmental noise levels, heart rate, mean arterial pressure and oxygen saturation is continuously measured. The statistical analysis of the influence of the equivalent noise level, rather than instantaneous noise level, on the behavior of the physiological variables is carried out. Great influence of noise is found by using this method, which is also easily translatable to other intensive care units as actual noise conditions are used in the investigation. Moreover, episodes of Bradycardia, Hypoxia and Hypertension are easily related to simultaneous direct nursing activity or a short but high enough noise event, suggesting that both sustained noisy environment and isolated peak noises lead to the alteration of the physiological variables.

1. Introduction

Noise, understood as being an undesirable sound for the recipient, turns out to be a regular feature of a Neonatal Intensive Care Unit (NICU) [1]. There are universally accepted recommendations for tolerable noise limits in neonatal units [2–4]. Nevertheless, noise levels detected in a number of NICUs often exceed these recommendations [5,6], bringing with them potential risks for the short and long-term development of newborns [7].

Among the numerous secondary effects of excessive noise experienced by premature newborns whilst in hospital [8], there are descriptions of changes in the cardio-respiratory system and of cerebral perfusion [7,9]. Stabilizing the immature infant's cerebral blood flow during the first few days of life has been put forward as one of the strategies to prevent the appearance of intraventricular hemorrhage (10). Moreover, the use of earmuffs in newborns improves sleep efficiency, increase the time of quiet sleep [11,12], reduces the fluctuation in oxygen saturation, stabilizes the behavioral state [13] and may facilitate weight gain [14].

There is little literature studying the response of extremely premature newborns to the habitual noise in a NICU during their first days of life and not using artificial, additional sources of noise. In most cases the patients are exposed to a high level of synthetic noise over short intervals of time (see [7] for a summary of previous research), that has little to do with the real conditions of ambient noise in a NICU. Williams et al. [15] established the variation of heart rate (HR) and mean arterial blood pressure (MABP) according to the level of environmental noise through the analysis of the temporal correlation of these variables measured second by second during a period of 15 min for a collection of eight neonates, obtaining a statistically significant, albeit rather low correlation between noise, HR and MABP. Slevin et al. [16] used another approach that consists of comparing averaged values of physiological variables, including HR, MABP and oxygen saturation (SpO_2), measured under conditions of quietness and the normal NICU environment. Results showed a significant decrease of MABP and a possible increase of HR during the normal period. However, the normal period includes discontinuous noise and infant nursing as well, so that it is not possible to distinguish the real effect of noise on the preterm infants.

In this manuscript, a procedure to evaluate the effect of noise on preterm infants is proposed, defining the periods of quietness, nursing and noisiness that take place during the normal activity of the NICU, and comparing the average, maximum and minimum values of HR, MABP and SpO_2 obtained in several of those periods.

2. Methodology

The proposed methodology consists of the statistical comparison of the average of several physiological variables measured

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Fig. 1. View of the incubator and the location of the outside microphone (top left of the picture).

under three different intervals of quietness, nursing and noisiness. The study protocol was approved by the Hospital Ethics Committee and Informed Consent was obtained from parents before measurements began.

The NICU patients' room contains up to seven incubators with its own equipment. The NICU is an "open doors" unit, with no restriction to parents' access, encouraging them to spend as much time in there as possible. The main noise sources of the NICU room are alarms, the opening and closing of the incubator's drawer and door, loud conversations, equipment ventilators, the sound of mobile phones, using furniture and normal conversations.

The patient studied was a preterm newborn, with a gestational age of 25 weeks and two days, and weighing 600 grams at birth. He is a second twin in a dichorionic-diamniotic pregnancy. The study was performed between the fifth and seventh day after birth. From birth, the patient had presented respiratory distress syndrome (for which he required mechanical ventilation and received two doses of intratracheal surfactant) and a patent ductus arteriosus, which was being treated with ibuprofen. He was treated with antibiotics for clinical suspicion of infection. Because he presented hemodynamic instability, an umbilical arterial access was inserted. The patient was also treated with a continuous infusion of morphine (1.5 mcg/kg/h) and was placed in a Giraffe Incubator® (Ohmeda company), which remained covered with a thick blanket during periods of rest.

Noise was continuously monitored for 56 h in two different locations [17]. The main position is inside the incubator, as close as possible to the infant ear position avoiding any chance of contact between the newborn and the microphone. It is intended in this position to measure the real noise exposure of the patient and thus reflections from the incubator are included as in practice. The secondary location is outside the incubator (Fig. 1), far away from any noise source, in order to avoid the direct field of any source and measure the quantity of environmental noise in the unit. The A-weighted equivalent sound level was measured every second ($L_{eq,A,1s}$) and recorded in a storage unit for post-process. The two sound level meters used in this study are Cesva C310 using Cesva PA13-697 microphones (Type I), and they were calibrated before and after the measurements using in field Cesva CB-5 calibrator.

In order to identify the source of the resulting noise levels, continuous direct observation was carried out by the research staff, writing down the source of the sounds and the approximate time interval of its occurrence. Nursing manipulation of the patient were also collected, since they can cause physiological changes in the neonate and produce a rather high sound level inside the incubator, circumstances that would lead to confusion in the data.

The patient's physiological constants were collected continuously by a Tram 451 M Module® and Solar 8000 M/i Monitor® (GE Medical Systems Information Technologies). The vital signs monitored by the Tram 451 M module which were used for the study were 12-lead ECG analysis, continuous invasive blood pressure and hemoglobin oxygenation (Masimo SpO_2). All information was transferred in real time to the MetaVision® Clinical Information System (*i*MDsoft), from which the data was extracted for the study using Matlab.

2.1. Data analysis

The instantaneous relation between noise levels and physiological time histories, given the great variability of the data, showed in the past a rather weak correlation [15]. In this study, the whole measurement time (56 h) was divided into different classes of intervals according to the following classifications: quiet, noisy and nursing. This procedure yielded several different time intervals *T* for each class.

Table 1
Noisy intervals without nursing.

Noise events	Time	Leq inside	Leq outside	Av HR	Max HR	Min HR	Av MABP	Max MABP	Min MABP	Av SpO_2	Max SpO_2	Min SpO_2
(a), (b), (c)	13:40–14:10	59.5	62.1	150.0	159.3	128	48.7	55.0	42	92.0	96.0	81
(d), (e)	16:50–17:10	60.1	65.7	144.0	149.0	124	49.8	54.3	44	97.5	98.6	94
(d)	1:55–2:05	64.0	65.8	143.7	147.0	139	51.2	62.6	44	96.5	97.0	95
(d), (e)	4:15–4:30	63.4	65.5	133.1	141.6	82	49.5	62.6	38	95.3	96.6	88
(d)	5:50–6:05	63.0	65.2	134.8	141.6	118	49.8	63.3	41	95.6	96.6	92
(d), (f)	8:15–8:30	63.3	65.8	128.1	139.3	77	50.6	61.6	38	91.7	94.0	88
(d), (f), (c)	10:45–11:00	63.6	65.9	147.9	155.6	139	46.5	55.3	33	92.7	94.0	89
(d), (f), (g)	11:05–11:20	63.5	65.9	143.2	150.3	110	49.1	63.3	41	90.3	94.0	84
(d), (e)	11:40–12:10	63.3	65.7	141.2	155.0	94	55.0	67.6	44	93.1	95.3	87
(d), (b), (f), (c)	13:15–13:25	63.1	65.6	148.6	153.6	137	53.0	56.0	43	93.3	94.6	92
(d), (g)	14:25–14:35	63.1	65.6	136.6	143.0	127	48.5	53.6	44	89.6	89.6	88
(d), (f), (e)	16:30–16:50	63.0	65.4	144.4	147.6	125	43.5	48.0	38	91.0	92.6	86
(f), (c)	19:30–19:40	62.9	65.4	158.4	162.6	151	–	–	–	91.3	94.0	87
(d), (e), (c)	9:20–9:35	62.7	65.6	164.9	169.6	156	–	–	–	84.9	97.6	66
(a), (g)	14:50–15:00	62.4	65.3	164.9	167.6	159	–	–	–	86.2	94.3	74
(a), (d), (e)	17:40–18:00	62.4	65.2	149.9	151.6	145	–	–	–	91.4	94.3	81
Average value	(260 min)	62.5	65.2	145.4	152.2	122	49.7	58.7	42	92.2	95.2	85

(a) Normal conversation. (b) Furniture. (c) Opening and closing the drawer of the incubator. (d) Alarms. (e) Opening and closing the portholes of the incubator. (f) Loud conversation. (g) Mobile phone.