# Environmental magnetic field in a Neonatal Intensive Care Unit. A relevant verification

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#### ABSTRACT

Preterm infants are born with immature organs, thus affecting the immune system. Electromagnetic fields influence melatonin production with low exposure levels. These infants require medical equipment 24/7 to recover, so they are constantly exposed to magnetic fields during their stay in the Intensive Care Unit. Our objective was to measure magnetic field levels generated around each incubator using a gauss meter and compare our results to the 2010 recommendations by the International Commission on Non-Ionizing Radiation Protection and the IEC 60601-1-2:2004 standard by the International Electrotechnical Commission (IEC). Among 11 hospitalized newborn infants, radiation was found within the recommended limits, but there was electromagnetic interference resulting from medical equipment layout problems in the unit. Key words: magnetic fields, melatonin, equipment and supplies.

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#### **INTRODUCTION**

The stay of preterm newborn infants in a hospital's intensive care unit is characterized by a delicate process of adaptation from intrauterine to extrauterino life.<sup>1</sup> These infants are born when their organs are still immature, so they tend to develop all types of diseases. In this situation, the immune system is committed to a constant fight to defend the body, so it is in a disadvantaged position against any external alteration.<sup>2-4</sup>

Non-ionizing radiation refers to radiation that does not carry enough energy to break ionic bonds. Low-frequency electromagnetic fields (EMFs) are a combination of electric and magnetic waves that travel simultaneously in the 0-300 Hz range and are usually expressed as magnetic flux density (B) or magnetic field strength (H) using the Tesla unit (T).<sup>5</sup> Units may be converted as follows:  $1 T = 104 G \text{ or } 0.1 \mu T = 1 \text{ mG}$ and  $1 \text{ A/m} = 1.26 \mu \text{T.}^6$ 

Medical equipment is a source of electromagnetic radiation and EMFs are considered harmful by the World Health Organization (WHO).<sup>7</sup> In this stage, due to the amount of medical equipment required by newborns infants for their recovery, they are exposed to uncontrolled radiation 24/7 while hospitalized.

In 1993, Russel Reiter and Jo Robinson published their book *Melatonin*,<sup>9</sup> which included a theory explaining that a reduced melatonin secretion, induced by EMFs, may lead to an increased incidence of cancer by reducing the immune and antioxidant defense provided by melatonin. This hypothesis was corroborated by several scientists and, in 2002, the team led by N. Cherry<sup>9</sup> demonstrated the ability of electromagnetic radiation to reduce circulating melatonin levels.

# MELATONIN AND ELECTROMAGNETIC FIELD IN A NEONATAL INTENSIVE CARE UNIT Melatonin

The pineal gland is a midline brain structure that converts serotonin into melatonin during the night.<sup>10</sup> Melatonin production is an essential signal for the internal synchronization of endocrine and non-endocrine rhythms, such as the sleep/wake cycle.<sup>11-13</sup> It is also a crucial part of the immune and antioxidant system

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Received: 2-8-2019 Accepted: 10-19-2019 because it assists in the destruction of free radicals.<sup>14</sup>

Exposure to low-frequency EMFs suppresses melatonin production because they have the ability of visible light to pervade the environment with their energy, thus impairing pineal gland performance to produce and secrete melatonin into the bloodstream.<sup>15</sup> During gestation, the fetus perceives, through the umbilical cord, their mother's emotions and circadian rhythm, thus secreting melatonin. Secretion levels are detected as of 24 weeks of gestation and gradually increase until birth.<sup>16,17</sup>

Newborn infants use this melatonin in the maturation of circadian rhythms in their first 72 hours of life because melatonin production is so imperceptible in the first week that the brain does not recognize it. Perceptible levels only start to be noticed 8 weeks after birth, increasing its production up to 50 % of adult levels<sup>18</sup> and stabilizing at about 2-3 months old and 3-5 months old in term<sup>18-20</sup> and preterm<sup>16</sup> newborn infants.

At the neonatal intensive care unit (NICU), lights are regulated, but they cannot be turned off during the night, as is the case of air conditioning and medical equipment used for newborn infant vital support, thus becoming the main sources of low-frequency EMFs. Melatonin production levels are subject to the light/dark cycle which, at the NICU, cannot be imposed. Therefore, the little melatonin production is altered, as well as the possibility of a faster recovery for an alreadycompromised immune system, thus creating the conditions for the development of opportunistic diseases,<sup>21</sup> leukemia,<sup>22</sup> and cancer<sup>20</sup> in the long term.

# Evidence of the effects of magnetic fields on fetuses and newborn infants

Since 2006, effects caused by exposure to EMFs have been observed in fetuses and newborn infants. They occur in the setting of long-term, sustained low doses. Human studies have demonstrated that gestational exposure is a window for the development of mutant blood cells that are only activated after birth and turn into leukemia cells.<sup>23,24</sup> Genotoxicity affecting deoxyribonucleic acid (DNA) creates a bond with the development of different cancers.<sup>25</sup> Damage occurs on the structure of selected brain cells and molecules;<sup>26</sup> the physiological and reproductive parameters of adults whose mothers were exposed to EMFs during pregnancy have also shown damage.<sup>27</sup>

Animal studies have demonstrated effects on the increase of serum iron levels<sup>28</sup> and high levels of cell death resulting from elevated endocrine indicators.<sup>3</sup>

Sources of fetal and neonatal exposure include computer (laptop)<sup>29</sup> and mobile phone use during pregnancy and neonatal incubators with high radiation levels.<sup>22,30</sup>

### Electromagnetic fields and medical equipment

IEC 60601-1-2 standard<sup>31</sup> establishes that medical equipment should operate in a magnetic field of 3 A/m = 3.78  $\mu$ T, while the recommendations by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)<sup>6</sup> indicate that people should not remain in a room where radiation exceeds 2 x 10<sup>-4</sup> T = 200  $\mu$ T. Expected levels inside an incubator are below 10 mG = 1  $\mu$ T; however, values up to 88.4 mG = 8.84  $\mu$ T have been observed in normal incubators and up to 357 mG = 35.7  $\mu$ T in transport incubators.<sup>32</sup>

The EMF decreases as the distance from the source increases. Therefore, an increased mattress thickness reduces EMF exposure levels. The material of the incubator frame also plays a major role. With plastic frames, the increase does not exceed 0.1 mG =  $0.01 \,\mu\text{T}$ ;<sup>32</sup> however, if they are made of iron, it may reach 500 mG =  $50 \,\mu\text{T}$ .<sup>32</sup>

#### Experience

The objective of this study was to measure lowfrequency EMFs generated in the environment of a NICU and their influence on incubators so as to verify whether magnetic induction levels, as established by the ICNIRP 2010 guidelines, and the values defined by the IEC standard for electromagnetic compatibility were within recommended limits to ensure newborn infant protection.

The study was conducted in the third and fourth week of April 2018 at the level III NICU of Hospital Ramón González Coro, a provincial referral facility for newborn infants with a birth weight of less than 1500 g. The NICU had 6 cubicles for the hospitalization of patients and beds were distributed depending on the treatment each newborn required.

Magnetic fields were measured using a PCE-G28 gauss meter. *Table 1* describes the technical specifications provided by the manufacturer.

### Methodology for measurements

- 1. The fields radiated by incubators were measured by positioning the sensor perpendicular to the incubator's outer walls and measuring the radiation that reached the 4 sides with the sensor placed at 1.0 m above ground level. It was rotated clockwise (from left to right) so as to recreate the same conditions for all measurements. This task was repeated for 5 days in a row, twice a day (morning and afternoon). Such measurement procedure was developed based on the bibliography and introducing specific features in relation to our objective.
- 2. Values were averaged.
- 3. Then, values were compared to those recommended by the ICNIRP 2010 guidelines for the general public and the electromagnetic interference limits set by the IEC, and subsequently plotted.

Data shown	Current measurement
Range	0 to 20 $\mu$ T/0 to 200 $\mu$ T/0 to 2000 $\mu$ T
Resolution	$0.01/0.1/1 \mu\text{T}$ (depending on range)
Accuracy	$\pm 4 \% + 3 d$ (in range 20 $\mu$ T)
	$\pm 5 \% + 3 d$ (in range 200 $\mu$ T)
	$\pm 10 \% + 5 d$ (in range 2000 $\mu$ T)
Frequency	30-300 Hz
Display	LCD screen
Weight	470 g
Power	9 V battery

TABLE 1. Technical specifications of the PCE-G28 gauss meter

d: digits.

#### Data collection

Preterm infants born before 37 weeks of gestation or with a birth weight of less than 2500 g and term infants with a birth weight of less than 5000 g were hospitalized at this NICU. These infants stayed at the NICU approximately 5 to 15 days if their condition was not very severe and up to several months if they had a very severe disease.

At the time of the study, 11 newborn infants were hospitalized and distributed among the cubicles as shown in *Table 2*, which also shows collected physical and technological data and magnetic field levels measured at each incubator. It was observed that cubicles D and E were smaller and medical equipment items were jumbled together, so the distance between them was measured to verify, based on the formula described in the IEC standard, that electromagnetic non-interference requirements between medical equipment items were met in terms of distance.

#### Significant aspects and recommendations

Values were measured outside the incubators due to biosafety concerns and in compliance with the epidemiological regulations of the Cuban Ministry of Health (MINSAP). The comparison of the average values with the recommendations by the ICNIRP and the IEC standard is shown in *Figure 1*, and it is observed that they are not exceeded.

The precautionary principle is applied when there is a high level of scientific uncertainty and a need to take measures against potentially

TABLE 2. Average measurement values	5 and population cl	haracteristics and tec	chnology per b	ved
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Cubicle	Equipment	Br (average)	Weight (g)	Gestational age (weeks)	Length of stay (day	s) Equipment
THERAPY B	Incubator 1	0.66 μT	2800	38.4	10	MPP
	Incubator 2	0.87 μΤ	1920	35	21	MPP; V
	Incubator 3	0.82 μΤ	1475	34.3	15	V; MPP; IP
	Incubator 4	0.30 μΤ	-	-	-	Out of service
THERAPY C	Incubator 1	$0.74 \ \mu T$	1480	29	30	V; IP; 2MPP; 2PP
THERAPY D	Incubator 1	0.47 μΤ	1585	32	15	MPP
	Incubator 2	0.78 μΤ	1680	32.4	15	MPP
	Incubator 3	$0.76 \ \mu T$	1620	32.4	15	MPP
THERAPY E	Warmer 1	0.45 μT	3600	40	5	-
	Warmer 2	0.70 μΤ	3125	36.2	5	-
	Warmer 3	$0.47 \ \mu T$	3480	41	5	-
	Warmer 4	0.34 μΤ	-	-	-	Out of service
	Warmer 5	$0.31 \ \mu T$	-	-	-	Out of service
THERAPY F	Incubator 1	0.13 μΤ	-	-	-	Out of service
THERAPY H	Incubator 1	$0.67 \ \mu T$	1240	30.3	45 1	MPP; V; MSD; IP; PP

Br: flux density; MPP: monitor of physiological parameters; V: ventilator; IP: infusion pump; PP: perfusion pump; MSD: medical suction device.

severe risks without waiting for the outcomes of further scientific investigations.<sup>33</sup> For this reason, respecting reference levels will warrant the respect of basic restrictions.

The following factors help to limit radiations: 1) incident field parameters; 2) characteristics of exposed body (size, internal and external geometry, and tissue dielectric properties); and 3) effects of electrical ground and reflection of other objects on the field close to the exposed body. For this reason, the dosimetry for non-ionizing radiation limits was defined by correlating the effects of temperature on the body, i.e., absorbed energy transformed into thermal energy.

Based on this principle, and to limit nonionizing radiation in the low-frequency range, the ICNIRP adopted a value of 1000  $\mu$ T for 50/60 Hz for occupational exposure with a safety margin large enough to prevent the stimulation effects of contact-induced currents under all possible conditions. They adopted the same criterion for reference levels for the general public and reduced them to a fifth, i.e., 200  $\mu$ T, thus preventing indirect adverse effects for more than 90 % of exposed individuals, especially considering children.<sup>6</sup>

Although measured values were far below the standard, it is worth paying attention to other matters, such as the situation in cubicle C, where there were too many equipment items around the incubator, which may have caused the resulting value. Or, for example, cubicles B and H, where incubators had been in use for 30 years and, even though they still stood in for comfortable fetal uterine conditions, they may have lost their electromagnetic compatibility feature.

Based on this criterion, this medical equipment should be replaced.

In addition, electromagnetic interference is one of the most important factors leading to increased EMF levels. This is because it always increases the existing field due to its additive capacity. Based on the studies done on this matter, it may cause either malfunctioning without any major complications or life-threatening conditions, or even lead to misdiagnosis due to false positive results.<sup>34</sup> For this reason, medical equipment compatibility, the distance between equipment items to prevent interference with one another, and environmental values for operation have been standardized by the IEC. Reviewing the cubicles, it was observed that in cubicles D and E some incubators were too close to one another so, since electromagnetic interference was suspected, distance was measured to implement the formula for the minimum distance for non-interference established by the IEC standard: D = 1,2  $\sqrt{P}$  (1), so as to determine if suspicions were true. Based on estimations, it was observed that this type of incubator should be more than 1.2 m away from



FIGURE 1. Chart to compare the study measurements to the standard values established by the International Electrotechnical Commission (IEC) and those recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)

EMFs: electromagnetic fields; IEC: International Electrotechnical Commission; ICNIRP: International Commission on Non-Ionizing Radiation Protection.

any equipment, which would reduce radiation values by 20 %, whereas in cubicle D, warmers should be at 1 m from one another. When observing the values for this cubicle, the 0.70  $\mu$ T measurement was determined between 2 sources, so an infant in that position is exposed to higher values and a greater risk.

To eliminate such interference, it is recommended to place medical equipment at a distance equal to or higher than estimated limits.

All measurements were within standard and expected values. This does not mean that this area should not be supervised because the effects on neonatal melatonin in incubators as of 0.2  $\mu$ T<sup>35</sup> up to 10  $\mu$ T have been reported; in addition, they start affecting the heart and cause chest angina and fibrillation,<sup>30</sup> and even heart attack when reaching 20  $\mu$ T.<sup>22,32</sup>

A strict surveillance of medical equipment distance is recommended because interference is imperceptible to the eye and increases radiation levels in the electromagnetic environment.

## CONCLUSIONS

According to measurements, the lowfrequency magnetic field was within the limits established by the ICNIRP 2010 guidelines and the IEC. Although values did not exceed those recommended by the ICNIRP and the IEC, it is worth noting that patients at the NICU received non-ionizing radiation 24/7, so it was very important to maintain the precautionary principle. These verifications should be extended to other facilities where these health care services are offered, because it is important to know the potential effects on future infant development.

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