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# Radiofrequency exposure in the Neonatal Medium Care Unit

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ABSTRACT

The aims of this study were to characterize electromagnetic fields of radiofrequency (RF-EMF) levels generated in a Neonatal Medium Care Unit and to analyze RF-EMF levels inside unit's incubators. Spot and long-term measurements were made with a dosimeter. The spot measurement mean was 1.51 ± 0.48 V/m. Higher values were found in the proximity to the window and to the incubator evaluated. Mean field strength for the entire period of 17 h was 0.81 (±0.07) V/m and the maximum value was 1.58 V/m for long-term RF-EMF measurements in the incubator. Values found during the night period were higher than those found during the day period. It is important to consider RF-EMF exposure levels in neonatal care units, due to some evidence of adverse health effects found in children and adults. Characterization of RF-EMF exposure may be important to further investigate the mechanisms and underlying effects of electromagnetic fields (EMF) on infant health. A prudent avoidance strategy should be adopted because newborns are at a vulnerable stage of development and the actual impact of EMF on premature infants is unknown.

## 1. Introduction

Advances in technology have had a significant impact on the field of medical applications. Medical applications use electromagnetic fields in the radiofrequency range (RF-EMF), in fact, most applications which emit EMF are in the frequency range above 100 kHz up to some GHz. The usual frequencies that are allowed for medical, industrial, and scientific, applications are similar to most industrial sources (Carranza et al., 2011). These are the frequency bands and sources used by the Global System for Mobile Communication (GSM) including the Industrial Medical and Scientific (IMS) band 2400 (2400, 2400–2483.5 MHz). Sources of exposure are apparatus used for electronic health records, biological monitoring and clinical treatment and diagnosis. RF-EMF sources of exposure are wireless communication systems (Calvente et al., 2015), incubator motors, transport incubators, radiant warmers and syringe pump systems. Besides, sources of different non-ionizing radiation of extremely low frequency and low frequency electromagnetic fields (ELF-EMF, LF-EMF), and optical radiation are mechanic ventilators, systems for monitoring of vital parameters, oxygen therapy devices, medical aspirators for secretions, portable wireless devices like tablets and laptop computers, and phototherapy lights for the treatment of hyperbilirubinaemia and skin diseases, respectively. The increasing use of electromagnetic fields (EMFs) frequency range from 0 Hz to 300 GHz, has resulted in some concerns regarding their biological effects on human health. Adverse and beneficial biological effects of EMFs have been described in laboratory animal (Riminesi et al., 2004) but the biological mechanism of such effects remains unclear. Biological effects depend not only on the distance to the source and size of the object but also on environmental parameters. For example, at lower frequencies of radiation (< 100 kHz) many biological effects are quantified in terms of current density in tissue and this parameter is most often used as a dosimetric quantity. At higher frequencies, several interactions are due to the rate of energy deposition per unit mass (Specific Absorption Rate, SAR) and SAR is therefore used as the dosimetric quantity. The high temperatures resulting from exposure to RF-EMF should also be taken into consideration (Kesari et al., 2013; Saunders et al., 2005).

Few studies have investigated the possible adverse health effects of RF-EMF exposure in children, who may be more vulnerable than adults to EMF (Kheifets et al., 2005a, 2005b; Schüz, 2005). However, it is important to state the special susceptibility of embryo, fetus and child during the development critical periods, because during these

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stages several feature, conducts and specific abilities are acquired (Artigas-Pallarés et al., 2011). Postnatal changes are characterized by slower growth and maturation of existing organ systems, particularly the central nervous system (CNS). Massive neuron proliferation, differentiation, and connections in the CNS are remarkably vulnerable. This allows a high capacity to acquire, assimilate, learn and remember some quick information without any big effort (Kheifets et al., 2005a, 2005b; Pinto, 2008). The development of the CNS is particularly susceptible to raised temperatures. A reduction in brain size, which results in a smaller head, is one of the most sensitive markers of heat-induced developmental abnormalities and can be correlated with heat-induced behavioral deficits (Saunders et al., 2005). Moreover, the lower bone density and lesser amount of fluid in the brains of children vs. adults may result in a deeper penetration of larger amounts of RF-EMF into the brain (Christ et al., 2010). Kane has suggested that exposure of the human embryo, fetus, and newborn to RF-EMF, an acknowledged environmental toxin under many exposure conditions, may be associated with an increased incidence of autism (Kane, 2004). Nevertheless, evidence that children are indeed more vulnerable to this exposure remains scant (Otto and von Möuhlendahl, 2007; Leung et al., 2011), and some studies have shown that effects in children did not differ from those in healthy adults (van Rongen et al., 2009; Croft et al., 2010; Segalowitz et al., 2010; Feychting, 2011; Valentini et al., 2011; Loughran et al., 2013). Studies that analyzed exposure to EMF in premature infants are mainly focused on ELF-EMF (ELF: frequency range 0 Hz to 300 kHz; in scientific literature, the exposure assessment to fields from 5 Hz to100 kHz is often referred to as ELF). Exposure to EMFs in incubators may modify the heart rate variability as well as other biological rhythms especially sensitive during perinatal period, thus having an impact on the autonomous nervous system, in newborns (Bellieni et al., 2008). In this sense, we consider highly vulnerable REM (Rapid Eye Movement) and No-REM sleep rhythms and also the acquisition of a melatonin circadian rhythm that takes place at the age of 6–8 months. This affects the autonomous nervous system in newborns and also in several functions related to maturation and neuronal plasticity. Some authors have found an association between exposure to ELF-EMF and low birth weight, and increased risk of spontaneous preterm birth and small for gestational age infants (de Vocht et al., 2014a, 2014b). Exposure to RF-EMF has also been related to higher risk of childhood leukemia (Calvente et al., 2010), neurodegenerative diseases (Kesari et al., 2013), behavioral problems (Divan et al., 2008; Thomas et al., 2010; Divan et al., 2012; Guxens et al., 2013; Huang et al., 2013; Calvente et al., 2016), and psychosocial risk (Sansone et al., 2013; Schoeni et al., 2015). Other studies found a negative impact on sleep-dependent performance improvement after exposure to RF-EMF, supporting its involvement in sleep-wake regulation (Lustenberger et al., 2013, 2015). Čermáková emphasizes the need to take a special care of newborns kept in incubators even if only the sub-reference values are detected. Babies in an incubator have much smaller dimensions, higher electric conductivity and may trigger another mechanism of response to ELF-EMF than those indicated in that paper (Čermáková, 2003). In the Neonatal Intensive Care Unit (NICU) babies spend their first hours or days of life in an incubator or in a radiant warmer. Modern incubators use the most advanced technology to provide thermal stability to low birth weight and sick newborns, thus improving their chances of survival (Antonucci et al., 2009). Incubators are enclosed cots made of transparent material with a padded mattress that is heated by convection, an external air filter, and sophisticated systems to monitor weight, breathing, heart and brain activity. The motor of incubators uses radiofrequency energy to operate and the lamps used in phototherapy are also sources of EMF (Bellieni et al., 2012). Like all electrical instruments, incubator motors are a source of EMFs radiating on its surrounding (Bellieni et al., 2005). The technological progress made in the development of more comfortable and safe infant incubators does not guarantee by itself an optimum microenvironment for premature and at risk neonates NICU. In fact, conventional noxious NICU environments and practices, including exposure to bright lights, high sound levels, and frequent noxious interventions, may negatively influence the development of the neonatal brain (Antonucci et al., 2009, Darcy et al., 2008). Premature infants are especially vulnerable to environmental exposure. Compared with term infants, premature infants have many physiological limitations, often experience CNS immaturity, and have an increased need for intensive care. These factors make preterm infants much more susceptible to the possible negative effects of the NICU environment (Darcy et al., 2008). Research reports indicate that RF-EMF exposure levels, typically encountered from some commercial products (a broad range of commercial RF-EMF energy product applications including, most notably, broadcast FM radio transmitters, radar, television, public service mobile communication transceivers, microwave ovens, and cellular phones) may induce alterations of biological processes or damage to the genome (Maes et al., 1993; Lai et al.,1996; Phillips et al., 1998; Luukonen et al., 2009). The review published by Juutilainen et al. analyses papers dealing with the biological effects of RF-EMF (Juutilainen et al., 2011). Considering several experimental models, different biological endpoints have been examined including genotoxic and non-genotoxic effects, gene and protein expression, carcinotoxicity and nervous system effects in animals and humans. Although the majority of studies reported no evidence of health effects, some studies reported effects on the human CNS but no consistent evidence has been found for carcinogenic or genotoxic effects. These authors and other studies emphasize that there are no biological or biophysical mechanisms that can explain such effects (Juutilainen et al., 2011, SCENIHR, 2013, 2015). Bellieni et al. analyze as to reduce the high ELF-EMF to which newborns are exposed in incubators and to which caregivers are exposed when working near the incubators (Bellieni et al., 2005). The impact of these EMFs on the enhanced sensitivity of the developing body is still largely unknown (Bellieni et al., 2005). The difficulty in making direct measurements of exposure to EMFs has needed to create measurement models. In this sense, Li et al. developed realistic anatomical models to evaluate human exposure to RF-EMF. Infants have significant physical and anatomical differences compared to other age groups. Investigating the effect of EMF exposure on infants is of particular importance, especially because their CNS undergoes rapid development (Li et al., 2015), and premature infants often stay in NICU for months. In addition, their results revealed that the safety limits prescribed by International Commission for Non-Ionizing Radiation Protection (ICNIRP) guidelines might not be conservative for exposure of infants to RF-EMF (Li et al., 2015; Antonucci et al., 2009). Besides current safety levels to EMFs are based on short-term or immediate effects, and it is important to consider that cancer and other diseases can have a long latency period (Calvente et al., 2010). Furthermore, there are few published data reporting the effects of EMF exposure on newborns in incubators, being the impact of EMF on infant health still unclear (Antonucci et al., 2009). Most of the scientific literature published on this topic is based on ELF-EMF exposure, as previously mentioned. Preterm or term newborns placed in incubators are considered an at risk group of particular interest because they are exposed to EMF from birth as they are surrounded by electrical equipment and general environment (multiple cellular phones, devices communicating wirelessly, and more traditional sources of exposure such as the radio) at the NICU. Some of these neonates have to stay at the NICU for a long time, growing in an EMF environment (Lai Thomas and Bearer Cynthia, 2008). There has been little research on the correlation between EMF exposures during the early phases of human development. In this respect more attention should be given to the exposure of developing embryos, fetuses, and young child to environmental toxins of all kinds because of their greater fragility and susceptibility. Fetuses and babies have a high number of stem cells which are responsible for the formation of the fetal nervous system (Franco et al., 2012). Stem cells are very sensitive to toxic effects. Thus, exposure of the fetus to EMF can increase the risk