



## **SECTION 19**

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# **Fetal and Neonatal Effects of EMF**

**Prof. Carlo V. Bellieni, MD**  
**Neonatal Intensive Care Unit**  
**University of Siena, Siena, Italy**

**Dr. Iole Pinto, PhD**  
**Director, Physical Agents Laboratory**  
**Tuscany Health and Safety Service, Siena, Italy**

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## I. INTRODUCTION

The exposure of the developing fetus and of children to electromagnetic fields (EMF) including both radiofrequency radiation (RF) used in new wireless technologies, and to extremely low frequency or power frequency fields (ELF-EMF) has raised public health concerns because of the possible effects (cancer, neurological effects, developmental disability effects, etc) from the long-term exposure to low-intensity, environmental level fields in daily life. This chapter documents some studies on RF and ELF-EMF that report bioeffects and adverse health impacts to the fetus, and young child where exposure levels are still well within the current legal limits of many nations. Several studies report adverse health effects at levels below safety standards [Kheifets and Oksuzyan, 2008; Comba and Fazzo, 2009; World Health Organization. 2007]; the evidence to date suggests that special attention should be devoted to the protection of embryos, fetuses and newborns who can be exposed to many diverse frequencies and intensities of EMF throughout their lifetimes, where the health and wellness consequences on these subjects are still scarcely explored.

The studies of fetuses and newborns are an important subset of those made on older children. Infants' exposure to EMF has raised concern recently, and some countries have developed guidelines to limit it, by avoiding the presence of hospitals or schools within a certain range of kilometers around high EMF emission sources [<http://www.emfs.info/Related+Issues/limits/>]. Nevertheless, children and babies are chronically exposed to many sources of EMF, in particular at home, where they can spend much time playing with computers and other wireless-enabled devices, watching television or near electronic baby monitors that emit RF in their cribs (or sleeping areas). These exposures are relatively new in the last two decades, and may represent a potential new carcinogen and neurotoxin, that, with chronic and indiscriminate exposure, may have health consequences in the long term.

## II. EMF AND RISK OF TUMORS

The evidentiary basis for evaluating an association between RF EMF exposure and brain cancer in children is much smaller than for adults [Wiedemann P, et al. 2009]. There is only one study available for mobile phone use. Elliott et al. [2010] found no association between risk of early childhood cancers (leukemia and non-Hodgkin's lymphoma, cancer of brain and central nervous system) and mothers' exposure to mobile phone base stations during pregnancy. Studies investigated brain cancer or leukemia with respect to EMF emitted from TV or radio transmitters

[Hocking et al. 1996; Dolk H, et al.1997; Cooper D, et al. 1997; Michelozzi P, et al. 2002; Park et al. 2004; McKenzie et al. 1998; Cooper et al. 2001; Maskarinec et al. 1994].

Few studies showed a significant increase of brain cancer in children with the use of cellular phones [Söderqvist et al. 2011; Merzenich et al. 2008], while some evidence exists for an association of RF EMF exposure to childhood leukemia. The argument for a causal influence of RF EMF exposure on leukemia in children is based on studies that found a statistically significant association between RF EMF exposure from radio or TV transmission towers and childhood leukemia. For instance, one case-control study [Ha, 2007.] found a significant increase for lymphocytic leukemia, but not for myelocytic leukemia in the highest exposure category.

Some authors suggested that genetic susceptibility to leukemia may amplify the adverse effects of magnetic field exposure, namely that the magnetic fields may have a causal role in the aetiology of leukemia among a genetically susceptible subgroup (i.e., children). For instance, Mejia-Arangure et al. [2007] observed a significant increase of childhood acute leukemia among Down syndrome subjects resident in dwellings with levels of magnetic flux density over 0.6  $\mu\text{T}$  (OR= 3.7; 95% CI: 1.05-13.3). A recent paper [Kheifets and Oksuzyan, 2008] specifically addresses leukemia and it indicates as a priority the study of highly exposed children who live in apartments next to built-in transformers or electrical equipment rooms, emphasizing the investigation of joint effects of ELF environmental exposure and genetic co-factors.

### III. EMF AND GENERAL HEALTH

Some studies address the question whether RF EMF exposure might cause general health disturbances in children [Milde-Busch et al. 2010; Heinrich et al. 2008; Divan et al. 2008; Söderqvist, 2008; Thomas, 2010; Vrijheid et al. 2010]. In a cross-sectional study Koivusilta et al. [2007] examined in a representative sample of 12–18-year-olds the association of mobile phone use with self-reported health status. Intensive use of communication technology, especially of mobile phones, was associated with health problems;. Van den Buick [2007] conducted a cohort study to assess the association between phone use by adolescents after lights out and levels of tiredness. Participants were adolescents with an average age of 14 in the youngest group and 17 in the oldest group. The authors found that those who used the mobile phone for calling and sending text messages after lights out were more likely to be very tired. Nevertheless, the results of these two studies were not proven to be due to EMF.

#### IV. EMF AND COGNITIVE FUNCTIONS

Original papers address the effect of RF EMF on cognitive function and CNS in children [Krause et al. 2006; Thomas et al. 2010; Abramson et al. 2009]. The age of the children investigated in these studies was in the range of 10–17 years. The argument supporting a causal influence of EMF exposure on cognitive function in children is based on the studies by several authors [Krause et al. 2006; Thomas et al. 2010; Abramson et al. 2009]. Lee et al [2001] administered three different tests that measure attention to 72 adolescents, who reported to either use a mobile phone or not. They found a statistically significant effect for one, the *Trail Making Test*. For the other two tests administered in the study, no statistically significant effects were found. The evidence for effects of RF EMF exposure on cognitive performance and CNS of children so far does not provide substantial hints for exposure-related changes. The very limited but provocative studies we do have suggest we cannot rule out that RF EMF exposure might influence cognitive and other CNS functions in children. If it is so, the consequences to public health can be enormous, if ignored.

#### V. FETUSES, NEWBORNS AND EMF

The early phases of human development have scarcely been studied with regard to their correlation with EMF. Nevertheless, the very young should receive more attention because of greater fragility and susceptibility of the developing embryo, fetus, and young child to environmental toxins of all kinds. Since fetuses and babies have a high number of stem cells and scarce immunity-mediated resources, any threat –in particular those due to physical and chemical agents – can have surprising and detrimental effects, since the environment influences even the DNA epigenetic expression [Davis and Lowell, 2008]. Czyz et al [2004] reported that GSM cell phone exposure affected gene expression levels in embryonic stem cells (p53-deficient); and significantly increased heat shock protein HSP 70 production. Belyaev et al [2010] reported that 915 MHz microwave exposure significantly affects human stem cells and may be important as a cancer risk. “The strongest microwave effects were always observed in stem cells. This result may suggest both significant misbalance in DSB repair, and severe stress response. Our findings that stem cells are the most sensitive to microwave exposure, and react to more frequencies than do differentiated cells may be important for cancer risk assessment and indicate that stem cells are the most relevant cellular model for validating safe mobile communication signals.”

In an animal study of mice, Aldad et al [2012] added support in a to the hypothesis that in-utero, whole-body exposure to RFR from cell phone radiation of the pregnant mother can result in hyperactivity, impaired memory and behavioral changes in the offspring.

Infante-Rivard and Deadman [2003] showed that maternal EMF exposure during pregnancy increased the risk of children 0-9 years of age developing leukemia (OR = 2.5, 95% CI = 1.2-3.0, for children of mothers in the highest 10% of exposure). Divan et al. [2008] reported that even prenatal exposure to cell-phone frequencies was associated with a significant increase in behavioral problems of emotion and hyperactivity around the age of school entry (OR = 1.80, 95% CI = 1.45-2.23). Although the results need replication, they point out an elevated susceptibility of the fetus and suggest a variety of adverse effects of cell-phone frequencies beyond just cancer. A recent study assessed that the exposure to EMF in pregnancy is linked to subsequent babies' asthma [Li et al. 2011].

Some researchers studied the possible effects of the exposure of fetuses to Magnetic Resonance Imaging (MRI) [Pediaditis et al. 2008]. Data seem to show that during abdominal MRI exposure limits of the mother "is not sufficient to protect the fetus if limits of the general populations are applied to it". In that case, fetal whole-body SAR exceeds limits by 7.4-fold. It is up to the physician and/or the ethics commission to decide upon justification for abdominal MRI of pregnant women if public safety limits are exceeded. The results indicate the need for specifically addressing fetal exposure to EMF and refining general recommendations by radiation protection bodies in line with the emerging science. Since the infant and young child are particularly vulnerable in general than adults, more care is needed to screen out unnecessary medical imaging of the pregnant woman and child and limit it to what is clearly medically necessary.

## VI. LAPTOP COMPUTERS AND FETUSES

Bellieni et al [2012a] assessed EMF exposure levels of the 26-week fetus in the womb of a pregnant woman using a laptop computer in tight contact with pregnant women's belly. The word "laptop" means "a portable, usually battery-powered microcomputer small enough to rest on the user's lap," and this means that they are often used at close contact with the body in a very delicate area close to skin, bones, blood, genitals, and in the case of a pregnant woman, very close to her fetus. Since LTCs are often used in tight contact with the body even by pregnant women, fetal exposures to extremely low frequency (ELF-EMF) magnetic fields and induced electric currents within the fetus are generated by these units. These fields pass directly through the mother's tissues to the fetus. We measured the ELF-EMF emissions in five models of portable computers of

different brands. Experiments were performed using a NARDA ELF 400 electromagnetic field measuring system (1 Hz to 400 kHz range) after determining the ambient background level was no higher than  $0.01 \mu\text{T}$ . The point of highest emission was measured at the surface of the laptop. The voxel model used to calculate intracorporal electric current density distributions was a whole-body human database of average pregnant woman, jointly developed by the National Institute of Information and Communications Technology and Ciba University, which represents a pregnant woman at the 26<sup>th</sup> week of gestation. In this model, mother and fetus tissues are defined according to NICT (National Institute of Information and Communications Technology) pregnant female voxel phantom. Dielectric properties of mother tissues are calculated using the parametric model developed by C. Gabriel and colleagues that reproduces the tissue conductivities in a wide range of frequencies. In the five brands of LTC we examined, ELF-EMF levels for their dominant frequency ranges from 1.8 to  $6 \mu\text{T}$ , whereas those produced from the power supply ranges from 0.7 to  $29.5 \mu\text{T}$ .

Induced electric currents were estimated for both the pregnant woman and the fetus. Statistical values of the averaged current density were evaluated for body tissues including the body of the fetus, and the grey and white matter of the brain of the mother; the mother's cerebellum, the mother's cerebrospinal fluid and mother's muscle tissue. In each case, the larger exposure was generated by the power supply rather than the laptop operation. Levels of induced current substantially exceeded ICNIRP public safety limits, assuming close proximity of the laptop to the belly of the pregnant woman (for the fetus, between 182% and 263.7% of the ICNIRP standard); and for the woman (between 346.7% and 483.5% of the ICNIRP standard).

Simple measures to distance the laptop during use (placing it on a table or desk and not on the body of the user) will result in significant reduction of ELF-EMF exposure and induced electric current in both mother and fetus.

## VII. NEWBORN (INFANT) INCUBATORS

Fetuses can also be born prematurely, and very often are protected in neonatal incubators for several weeks. Only a few studies of incubators (or isolettes) have assessed ELF-EMF magnetic field exposures to the newborn baby inside an incubator where the source is a motor that generates these emissions. The motors of neonatal incubators produce electromagnetic fields in their vicinity. Although premature babies are often exposed to incubator ELF-EMF for months, little research has been done into the effects of EMFs on newborns, and most has regarded newborn

animals [Luchini and Parazzini, 1992; Watilliaux et al. 2011; Orendáčová et al. 2011; Miyakoshi et al. 2012] so that the impact of this emission on the developing body's enhanced sensitivity to environmental insult is still largely unknown. In order to determine safe distances, ELF-EMF emissions must be measured and mapped, and these exposures need to be reduced to levels below that reported to cause adverse health effects in children (at or below  $0.01 \mu\text{T}$ ). To allow what is an essential medical intervention for the growing premature baby, or the sick infant who needs exceptional care following birth, at least two possible solutions to reduce ELF-EMF levels are:

- Designing incubators with the motor far from the baby (some incubators already have adopted this measure) and
- Using ELF-EMF absorbing panels to shield the baby's body from emissions (like Mu metal).

In Bellieni et al [2003], ELF-EMF levels are characterized in some common neonatal incubators. Levels of magnetic flux density at mattress level well over 10 milliGauss (mG) at mattress level: up to 88.4 mG in common incubators, and up to 357.0 mG in a transport incubator. These values are in line with those of two previous studies on ELF-EMFs in infant incubators [ Lie and Kjaerheim, 2003; Babincova et al. 2000; Lie and Kjaerheim, 2003], and higher than the values recorded in two other reports [Aasen et al. 1996; Ramstad et al. 1998]. Another paper showed that nurses are also exposed to high EMF while working near incubators [ Bellieni, 2002].

Bellieni et al [2008] reported that the exposure to high electromagnetic fields can interfere with the sympathetic nervous system in altering babies' heart rate variability. Heart rate variability (HRV) of 43 newborns in incubators was studied. HRV is an index of Autonomous Nervous System activity. The study group comprised 27 newborns whose HRV was studied throughout three 5-minute periods: 1) with incubator motor on, 2) with incubator off, and 3) with incubator on again, respectively. Mean HRV values obtained during each period were compared. The control group comprised 16 newborns but exposed to no source of ELF-EMF; they were exposed to changes in background noise similar to those provoked by the incubator motor (to reproduce the conditions of the first cohort). Mean total power and the high-frequency (HF) component of HRV increased significantly and the mean low-frequency (LF)/HF ratio decreased significantly when the incubator motor was turned off. Basal values were restored when incubators were turned on again. Changes in background noise did not provoke any significant change in HRV. We therefore concluded that ELF-EMFs produced by incubators influence newborns' HRV, showing an influence on their

autonomous nervous system. More research is needed to assess possible long-term consequences, since premature newborns may be exposed to these high ELF-EMFs for months.

Even melatonin production – as was signaled in adults [Wilson et al. 1989] – was inhibited in the newborn by exposure to ELF-EMF [Bellieni et al. 2012b]. The study concerned 28 babies (study group), who had spent at least 48-hr in common incubators with the presence of significant ELF-EMF. Measurements of mean 6-hydroxy-melatonin-sulfate (6OHMS) urine excretion were recorded at the end of their stay in the incubators, and compared with their mean 6OHMS excretion after having been put in cribs, where EMF are below the detectable limit ( $<0.01 \mu\text{T}$ ). Mean 6OHMS/cr values were respectively  $5.34 \pm 4.6$  and  $7.68 \pm 5.1 \text{ ng/mg}$  ( $p=0.026$ ) when babies were exposed to ELF-EMF in incubators, and after having been put in the crib. We have compared these changes with a control group of babies, who were not exposed to EMF either before the first sampling nor before the second. We therefore measured urine 6OHMS twice, with an interval of 48-hr, in a control group of 27 babies who were not exposed to EMF during both samples. In the control group, mean 6OHMS/cr values in the first and in the second sample were respectively  $5.91 \pm 5.41$  vs  $6.17 \pm 3.94 \text{ ng/mg}$  ( $p=0.679$ ). The transitory increase in melatonin production soon after removing newborns from incubators demonstrates a possible influence of EMF on melatonin production in newborns. We should point out that the two groups were similar in all but their mean corrected age. It was greater in the control group (the time as measured from conception).

## VIII. CONCLUSIONS

Some studies [Lowenthal et al. 2007; Infante-Rivard and Deadman, 2003] report that the fetus and young children are at greater risk than are adults from exposure to environmental toxins. This is consistent with a large body of information showing that the fetus and young child are more vulnerable than older persons are to chemicals [Makri A, et al. 2004] and ionizing radiation [Preston, 2004]. These considerations have led the US Environmental Protection Agency (EPA) to propose a 10-fold risk adjustment for the first 2 years of life exposure to carcinogens, and a 3-fold adjustment for years 3 to 5 [[http://www.epa.gov/sab/pdf/sab\\_04003\\_resp.pdf](http://www.epa.gov/sab/pdf/sab_04003_resp.pdf)].

This susceptibility may be why, according to some authors (60) [Carpenter and Sage, 2008], “the evidence for the relation between magnetic field exposure and leukemia in children is stronger than that for adults”.



The World Health Organization Agency International Agency for Research on Cancer (or IARC) classifies both ELF-EMF and RF EMF as Possible Human Carcinogens or Group 2B [<http://microwavenews.com/news/backissues/j-a01issue.pdf>]. These proposed US EPA adjustments do not deal with fetal risk, and the possibility of extending this protection to the fetus should be examined, because of fetus' rapid organ development. Classification of these related electromagnetic field exposures (ELF-EMF and RF EMF) as having the potential for serious potential health consequences for adults certainly justifies additional protections for the fetus, the newborn and young children who have greater sensitive to such exposures. Further, there is good evidence to suggest that many toxic exposures to the fetus and very young child have especially detrimental consequences depending on when they occur during critical phases of growth and development (time windows of critical development), where such exposures may lay the seeds of health harm that develops even decades later. See Appendix 1 for international statements of concern and delineation of priority research needs published by the WHO and US National Academy of Sciences, National Research Council.

Important bioeffects and some adverse health effects of chronic exposure to low-intensity (non-thermal) non-ionizing radiation have been reported on babies, and important open questions still remain.

Existing FCC and ICNIRP public safety limits seem to be not sufficiently protective of public health, in particular for the young (embryo, fetus, neonate, very young child).

The World Health Organization International Agency for Research on Cancer has classified both ELF-EMF and RF EMF (wireless radiofrequency) as Possible Human Carcinogens (Group 2B).

New, biologically-based public exposure standards are critically needed.

Common sense measures to limit both ELF-EMF and RF EMF in these populations is needed, especially with respect to avoidable exposures like incubators that can be modified; and where education of the pregnant mother with respect to laptop computers, mobile phones and other sources of ELF-EMF and RF EMF are easily instituted.

It is not in the public interest to wait: A precautionary approach may provide the frame for decision making where remediation actions have to be realized to prevent high exposures of children and pregnant woman.

## APPENDIX 1

### INTERNATIONAL STATEMENTS

#### World Health Organization Research Agenda for Radiofrequency Fields (2010) Children and EMF: Related Recommendations by World Health Groups

In 2010, the WHO produced a research agenda to address growing scientific questions and public concern about health effects of radiofrequency radiation, particularly with the explosive rise in exposures from new telecommunications technologies. It replaced a 2006 research agenda developed by the International EMF Project.

#### **Priority: Epidemiology**

**High** - *Prospective cohort studies of children and adolescents with outcomes including behavioural and neurological disorders and cancer*

*Rationale: As yet, little research has been conducted in children and adolescents and it is still an open question whether children are more susceptible to RF EMF since the brain continues to develop during childhood and adolescence. also, children are starting to use mobile phones at a younger age, given the existence of large-scale cohort studies of mothers and children with follow-up started during or before pregnancy, an RF sources component could be added at a reasonably low cost. Billing records for mobile phones are not valid for children, therefore the prospective collection of exposure data is needed. for neuropsychological studies, one challenge is to distinguish the “training” of motor and neuropsychological skills caused by the use of a mobile phone from the effects of the RF field. any future study should try to address this issue. in any case it should be of longitudinal design, thereby allowing the study of several outcomes and changes in technology and the use of mobile phones as well as other sources of RF EMF exposure, such as wireless laptops.*

#### **Priority: Human studies**

**High** - *further RF EMF provocation studies on children of different ages*

*Rationale: current research has focused primarily on adolescents; very little is known about possible effects in younger children. longitudinal testing at different ages, for example by studying children already participating in current cohort studies, is recommended. This would allow consideration of the influence of potentially confounding factors such as lifestyle.*

#### **Priority: Animal studies**

**High** - *Effects of early-life and prenatal RF exposure on development and behaviour*

*Rationale: There is still a paucity of information concerning the effects of prenatal and early life exposure to RF EMF on subsequent development and behaviour. Such studies are regarded as important because of the widespread use of mobile phones by children and the*

*increasing exposure to other RF sources such as wireless local area networks (Wlans) and the reported effects of RF EMF on the adult EEG. Further study is required which should include partial (head only) exposure to mobile phones at relatively high specific absorption rate (SAR) levels.*

### **National Research Council, National Academy of Sciences (2008)**

The U.S. Food and Drug Administration (FDA) of the Department of Health and Human Services asked the National Academies to organize a workshop of national and international experts to identify research needs and gaps in knowledge of biological effects and adverse health outcomes of exposure to radiofrequency (RF) energy from wireless communications devices. To accomplish this task, the National Academies appointed a seven-member committee to plan the workshop (Committee on Identification of Research Needs Relating to Potential Biological or Adverse Health Effects of Wireless Communications Devices.). In their report, the Committee recommended these actions with respect to RF exposure for the developing fetus, and for young children:

- Characterization of exposure to juveniles, children, pregnant women, and fetuses from personal wireless devices and RF fields from base station antennas.
- Prospective epidemiologic cohort studies of children and pregnant women.
- Epidemiologic case-control studies and childhood cancers, including brain cancer.

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