

An inventory of teratologic studies
by Peter Thalau

Embryonic development at exposure to low-frequency and radio-

Introduction

Electromagnetic fields (EMFs) are part of our natural environment and are used for direction orientation by various animals (for example fish or birds). However, because of the accelerated technical development which has taken place since the start of the 20th century, the overall exposure to EMFs is steadily increasing. Now, the question is whether or to what extent EMFs are capable of affecting biological systems and, particularly, the human organism. Since the 1980s there has been discussion on the possible effects on embryonic development caused by EMFs, and in the last ten years a great number of studies has been performed on this issue. Many of these studies were published in relatively unknown or difficult-to-obtain journals. Therefore, this survey study will try to present an inventory of available studies on this topic area. Because of the huge number of current studies it was impossible to consider all studies. So, for example, we had to confine ourselves to analysing study results published in English or German.

Teratology

Teratology (Greek *teratos* = monster) is a branch of embryonic research dealing with inborn malformations. The causes of these malformations are claimed to be genetic factors on the one hand, and environmental factors on the other. However, the causes of most malformations are not

known. It has been estimated that 7-10% of malformations of known origin are due to environmental factors alone; for another 10% genetic factors are held responsible. Regarding the by far greatest part (about 80%), it has been suggested that a combination of both genetic and external influences is responsible. The fact that some organisms genetically tend to respond more strongly to teratogens than others is summed up by the term "genetic disposition".

The term "teratogens" stands for external influences causing inborn malformations. Known teratogens for humans are viruses such as, for example, the Rubella (German measles) and the Herpes Simplex virus, or chemical substances such as pharmaceuticals (for example thalidomide), synthetic hormones (for example cortisone), and chemicals present in the environment (for example herbicides).

As embryonic development is strongly characterised by cell multiplication, it is particularly at risk of being affected by teratogens. Different organs and tissues are affected during various phases of development.

Embryonic development is sub-divided into three phases. The first phase (blastogenesis) extends from egg cell fertilisation to the development of the three blastemas from which derive all tissue types. During this phase, teratogens can either damage so many cells that the embryo may die, or only a few cells are affected so

frequency electromagnetic fields

that regulatory mechanisms are able to compensate for the damage and malformations are avoided. During the second phase, the embryonic phase, organs are formed. Therefore this phase in humans, extending from 4th to 8th week of pregnancy, is highly sensitive to teratogenic influences. The foetal period – the third stage – essentially is when foetal growth takes place. At this point, only a few organic system cells, such as the ones of the brain, specialise in preparation for coming tasks; correspondingly, sensitivity to teratogens decreases.

The chicken embryo as a test model

As *in vivo* experiments in human embryos cannot be performed for ethical reasons, teratologic laboratory tests are done in animals. Because of their common properties during embryonic development, reptiles, birds and mammals are used. Usually, teratogens reach the embryo via the mother's metabolism and blood circulation. Therefore, mammals are often used as a test model. But due to the physical properties of EMFs, one can rightly assume that they could directly affect the embryo, too. Thus, bird embryos generally are seen as being appropriate for use in research. In fact, many experiments on possible teratogenic effects of EMFs are performed in chicken embryos. The use of chicken embryos has several advantages. The embryos are directly ex-

posed to EMFs, protected only by the eggshell. In contrast, mammalian embryos are partially shielded by the mother. This shielding effect is different for different test animals since, for example, differences in body size and fatty deposits play an important role. Thus, it is impossible to exactly determine the field conditions that individual embryos are exposed to. Also the portability of results is questionable. Generally, as a model for mammals, rats and mice are used; the shielding effects of the mother in both are far smaller than in the much bigger humans. Moreover, during tests in mammalian embryos field conditions are difficult to keep at a constant level since the animals move freely about the cage making it difficult to compare results across test animals. In other words, there is the possibility that embryos respond to continuous alterations of field conditions. A further advantage is that results gained from chicken embryos are not falsified by potential secondary effects affecting the embryo via the mother. Such potential secondary effects could be caused by EMFs but also by an unknown disease of the mother or by a condition of incorrect positioning.

However, before drawing conclusions about humans based on results gained from animal tests, we should bear in mind that chicken eggs compared to humans have a distinctly higher absorption capability in the resonance range.

Methodological approach

Methodologically, first of all, a distinction was made between laboratory studies and epidemiological studies. Further, we subdivided the studies according to low-frequency and radio-frequency EMFs, and according to the type of living creatures examined (chickens and mammals) as well as models employed (cell and tissue cultures). Although our intent has been to provide an unbiased presentation, it was necessary to consider critically those published results which were obviously being at odds with the present state of knowledge or expected effects, and to indicate where any suggestion exists for an invalidity in results arising from faulty test design and performance.

Conclusions

The results of the studies dealt with in this paper, are partially contradictory. There are several reasons for this. Mostly, different frequencies were examined, and, as a rule, there also were substantial differences between test designs, such as for example the chosen durations and times of day of EMF exposure. Moreover, individual studies often examined different biological parameters, for example malformation rate or embryo mortality. In this context, we have to distinguish between the terms “embryo mortality” and “teratogenic effects” since not only in-born malformations can lead to embryo loss.

To resolve this problem six working groups from four different countries joined efforts in the "Henhouse Project." Within this project, the working groups performed identical experiments on exposure of chicken embryos to a low-frequency EMF in their individual countries. In spite of that, no uniform results could be found. Four groups could not detect any statistically significant effects, whereas two succeeded in doing so. A possible explanation is the different genetic nature of the embryos. Although the examined eggs all came from chickens of the same type, in the experiment eggs of different hens and roosters were used. The differences between genetic backgrounds could have led to result variations.

On the whole, tests in humans carried out to this date do not confirm any association between exposure to low-frequency EMFs and teratogenic damage. Nonetheless, some tests in chicken embryos did show significant effects. However, here only the early stages of embryonic development were examined; the later stages up to hatching were not documented. But damage occurring during these early phases may lead to different results: either they result in the death of the embryo, or they have no effect at all due to special repair mechanisms. During experiments in mammalian embryos, 56% of the investigations showed statistically-significant effects. However, these results related to a number of different parameters, so that there were much lower percentages for individual parameters. Embryo mortality, for example was increased in only 12% of the cases. In summary, we can say that the effects observed in mammalian embryos either were not replicable or were confined to certain breeding lines.

Some tests applying radio-frequency EMFs show statistically-significant differ-

ences between test and control groups. However, these effects in the main part may be explained by the thermal impact of exposure to radio-frequency EMF. Some of the investigations using chicken embryos were noticeable for their faulty test design. Here, probably too low or too high incubation temperatures were responsible for increased embryo mortality. We still should point to a single study showing an embryo mortality rate of up to 100% at exposure to a radio-frequency EMF. All embryos died during the third week of incubation, shortly before hatching and seemingly without showing malformations. Both aspects provide evidence for the suggestion that the increased mortality is not due to teratogenic effects of EMF but to a wrong incubation temperature. Concerning this study, there is some doubt about the authors' objectivity, since they obviously had an interest in promoting a certain shielding antenna to be introduced onto the market. Presently, the risks asserted to exist resulting from the use of mobile phones and mobile radio networks cannot be confirmed since the few studies performed in the relevant frequency spectrum show only small effects, or no effects at all.

To date the available data gained from a series of cell-biological investigations has provided no proof of effects of the EMF which was used on either the genotype or the whole cell. However, there is a complete lack of investigations undertaken in the 1.8-GHz range.

Of great interest are studies dealing with the question whether EMF exposure potentially may decrease or increase effects of teratogenic substances. In this area, there are some *in vitro* tests but no *in vivo* studies available. Of special importance would be studies investigating a reinforcing or contradictory effect of EMF and factors such as strain, diseases or nutrition.

The results of available epidemiological studies provide no evidence for an increased risk for pregnant women caused by low-frequency EMF. We still cannot draw valid conclusions about possible effects of mobile radio stations and mobile phones since presently available data are insufficient.

Summary

Despite the great number of published studies, not all questions concerning this topic area can satisfactorily be answered as yet. Thus, in the opinion of the author, research efforts certainly have to be continued.

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