Bundesamt
für Strahlenschutz

Spotlight on EMF Research

Spotlight on “The international collaborative animal study of the carcinogenicity and genotoxicity of mobile phone radiofrequency radiation” by Imaida et al. (Japanese study) and Kim et al. (Korean study) in Toxicological Sciences (2026)

Category [radiofrequency, animal study]

Spotlight - Jun/2026 no.1 (Eng)

Competence Centre for Electromagnetic Fields (KEMF)

1 Context

It has long been hypothesised that radiofrequency electromagnetic fields (RF-EMF) are carcinogenic, i.e., have the potential to induce cancer. After the International Agency for Research on Cancer (IARC) classified RF-EMF as possibly carcinogenic to humans in 2011, new studies have investigated their carcinogenic potential in humans and animals. In 2018, the U.S. National Toxicology Program (NTP) concluded that there is clear evidence of carcinogenic activity of RF-EMF exposure, particularly for cardiac schwannomas of the heart in male rats exposed at high levels [3]. These results prompted further investigation. To evaluate reproducibility of the NTP findings, an international two-site collaboration was initiated, resulting in the Japanese [1] and the Korean [2] studies.

2 Results and conclusions from the perspective of Imaida et al. and Kim et al.

The international collaborative project was designed as a chronic bioassay starting in 2019 and was conducted in parallel in Korea and Japan. The study protocols were harmonised to ensure consistency and comparability of the results. Since the NTP study found an increased incidence of tumours primarily in male rats in the heart, brain, and adrenal glands, the two studies used only male rats of the same strain and from the same supplier as the NTP study.

The exposure regimen for the preliminary, 2-year, and genotoxicity studies was identical. In detail, animals were exposed or sham-exposed to 900 MHz CDMA-modulated RF-EMF at 4 W/kg whole-body average specific absorption rate (wbSAR). A group of 70 cage control animals that did not receive any treatment was also included. RF-EMF exposure was conducted for 18 hours and 20 min per day, structured as two periods with 10 min on/off cycles. Exposure started in utero from gestation day 5 and continued after weaning of the pups for 28 days, 104 weeks (2-year study), or 14 weeks (genotoxicity study), respectively. Only male offspring were included in the studies and examined after birth.

In the 28-day preliminary studies, the feasibility and safety of the 4 W/kg wbSAR exposure were confirmed. There were no RF-EMF-related adverse effects on reproductive performance of the dams. Small statistically significant changes in some hematology/clinical chemistry parameters and organ weights were observed but lacked pathological correlates and were not judged to be toxicologically significant. Compared to the sham-exposed rats, RF-EMF-exposed dams and pups showed reduced body weights and food consumption at various time points before and after weaning. Pups also showed differences in body temperature.

In the Japanese and Korean 2-year carcinogenicity studies, 70 male offspring per study were selected from each group and either exposed or sham-exposed for 2 years. The following results were reported:

- Reproductive performance: There were no RF-EMF-related adverse effects on reproductive performance of the dams. During lactation, body weights of dams and pups were lower in the RF-EMF-exposed group compared to the sham-exposed group. During gestation and lactation, food consumption of dams was lower in RF-EMF-exposed than sham-exposed rats. In the offspring, RF-EMF-exposed rats consistently consumed less food for most of the 2-year exposure period. Depending on the time point, this ranged from around 8% to over 30% less food consumption. In addition, RF-EMF-exposed rats had lower body weights compared to sham-exposed rats from the first few weeks of the 2-year exposure period onwards. However, the body weights were comparable by the end of the study.
- Survival rate: In the Japanese study, RF-EMF-exposed male offspring exhibited statistically significantly higher survival at week 105 (64.7%) than sham-exposed rats (42.9%). In the Korean study, there were no statistically significant differences in survival (week 104: RF-EMF-exposed 58.6%, sham-exposed 54.3%), although after week 60, survival declined more rapidly in the sham-exposed group.
- Neoplastic lesions: Regarding neoplastic lesions (benign, malignant, or total tumours), neither study found statistically significant, exposure-related increases in major organs of concern, including brain,

heart, and adrenal gland (see table 1), which were concluded to be targets of carcinogenic effects of RF-EMF exposures in the NTP study [3].

- Non-neoplastic lesions: In the Korean study, several statistically significant reductions of non-neoplastic lesions were found in the adrenal glands of RF-EMF-exposed rats. According to the authors, these findings suggest that RF-EMF exposure may be associated with reduction in certain hyperplastic and vacuolative changes in the adrenal glands, although the biological significance remains unclear. In the Japanese study, several non-neoplastic lesions showed statistically significant differences (increases and decreases) between groups, but most were judged incidental because they occurred predominantly in long-surviving animals and lacked a consistent exposure-related pattern.
- Chronic progressive nephropathy: In both studies, a statistically significant reduction in the incidence of chronic progressive nephropathy was observed in RF-EMF-exposed compared to sham-exposed rats (see table 1). As discussed by the author teams, this finding may be linked to lower food intake and body weight and to longer survival in the Japanese study. The incidence of progressive cardiomyopathy did not differ between the groups in either study.

		Korean study		**Japanese study**	
		Number of animals with lesion (incidence)			
Organ	**Lesion**	**RF-EMF exposed**	**Sham-exposed**	**RF-EMF exposed**	**Sham-exposed**
Heart	Endocardial schwannoma	2/70 (2,9%)	0/70 (0%)	1/68 (1%)	1/70 (1%)
Brain	Glioma (NOS)	1/70 (1,4%)	1/70 (1,4%)	1/68 (1%)	0/70 (0%)
	Malignant meningioma	0/70 (0%)	1/70 (1,4%)	**Not reported**	**Not reported**
	Benign granular cell tumour	**Not reported**	**Not reported**	0/68 (0%)	3/70 (4%)
	Malignant granular cell tumour	2/70 (2,9%)	1/70 (1,4%)	**Not reported**	**Not reported**
Adrenal gland	Adrenal cortical carcinoma (carcinoma, cortex)	0/70 (0%)	1/70 (1,4%)	1/68 (1%)	0/70 (0%)
	Benign pheochromocytoma	14/70 (20%)	15/70 (21,4%)	9/68 (13%)	7/70 (10%)
	Complex benign pheochromocytoma	0/70 (0%)	1/70 (1,4%)	**Not reported**	**Not reported**
	Malignant pheochromocytoma	3/70 (4,3%)	1/70 (1,4%)	0/68 (0%)	1/70 (1%)
	Complex malignant pheochromocytoma	**Not reported**	**Not reported**	1/68 (1%)	0/70 (0%)
	Adenoma (cortex)	**Not reported**	**Not reported**	1/68 (1%)	3/70 (4%)
Kidney	Chronic progressive nephropathy	49/70 (70%)	65/70 (93%)	54/68 (79%)	67/70 (96%)

Table 1: Overview of major neoplastic lesions and chronic progressive nephropathy of exposed and sham-exposed rats in the Korean and Japanese 2-year carcinogenicity studies.

The Japanese and Korean genotoxicity studies were conducted in parallel with the 2-year carcinogenicity studies. After end of exposure, the alkaline comet assay and micronucleus test were performed to assess DNA and chromosomal damage, respectively, in various tissues of the rats. In the Korean study, the pig-a gene mutation assay was also performed. No statistically significant differences were observed between RF-EMF-exposed and sham-exposed groups in the genotoxicity tests.

The author teams of both studies concluded that the results of their chronic cancer bioassays do not provide evidence of carcinogenic or genotoxic effects of long-term, CDMA-modulated 900 MHz RF-EMF exposure at 4 W/kg wbSAR in male rats. Findings of malignant schwannoma in the heart were not statistically significant and therefore regarded as being most likely incidental and not supportive of a causal relationship with RF-EMF exposure.

3 Comments by the BfS

Robustly designed, large-scale studies are essential to validate the findings of the NTP study and to determine whether RF-EMF exposure can increase cancer risk. In this context, the Japan-Korea collaborative study offered a valuable and promising approach.

The author teams of both studies mention that the Japan-Korean collaborative study is not an exact replication of the NTP study with respect to the notable findings in male rats after RF-EMF exposure, because several key aspects are not identical. For example, there was only one exposure level at 4 W/kg compared with three exposure levels in the NTP study (1.5, 3, and 6 W/kg). Several procedures, including a preliminary 28-day study, the intermittent exposure protocol, and duration of exposure were the same as in the NTP study.

Neither the Japanese nor the Korean study showed any statistically significant increase in the incidence of neoplasms in the heart, brain, or adrenal gland. According to the author teams, these results are inconsistent with the findings of NTP and they suggest that the few individual cases of heart schwannomas and brain tumours in their studies are incidental and not related to RF-EMF exposure.

From the BfS's perspective, this cannot be concluded unequivocally, and uncertainties remain. Although there was no statistically significant effect, single cases of tumours in the RF-EMF-exposed group were observed, including three schwannomas in the heart and two gliomas in the brain as opposed to one case of each in the sham-exposed group, when combining both studies (see table 1). Those results are not necessarily inconsistent with the NTP results, because the effect estimates of both independent studies point in the same direction, albeit with very wide 95% confidence intervals that overlap the other study's point estimate[1]. In addition, several aspects need to be considered when comparing the results of the collaborative study to the results of the NTP study:

1. The statistically significant effects in the heart and brain reported in the NTP study are based on the noticeable findings in the group exposed to 6 W/kg. This exposure level is significantly higher than the 4 W/kg used in the collaborative study. At the lower exposure levels of 3 and 1.5 W/kg, however, the NTP study showed no statistically significant effects on tumour counts in pairwise comparisons with the sham-exposed controls.
2. In the NTP study, a statistically significant positive trend over 0, 1.5, 3, and 6 W/kg for heart schwannomas and malignant gliomas was observed. Since only one exposure level was investigated in the collaborative study, the presence of such a trend could not be examined.
3. The individual Japanese and Korean studies used lower numbers of animals per group than the NTP study (70 vs 90) which reduces their statistical power. It means that the ability to detect a difference in the number of rare tumours, like heart schwannomas and brain tumours [4], between exposed and sham-exposed groups was limited in the two studies. This is also regarded as a limitation by the author teams.

It is therefore uncertain whether statistically significant increases would have been detected if a higher SAR level and/or a higher number of animals per group had been used. It would be interesting to know, whether combining the results of the Japanese and Korean study would result in statistically significant effects.

[1] Internal BfS calculation. The animal and case counts from the Japanese and Korean studies were summed; for comparison, the animal and case counts from the two experimental groups (GSM and CDMA modulation) of the NTP study were also combined, in each case separately for the exposure levels closest to the collaborative study, 3 and 6 W/kg.

Another discrepancy between the Japanese and Korean studies and the NTP study refers to the results of the comet assay in male rats. Both the Japanese and the Korean study reported that RF-EMF exposure resulted in no genotoxic effects. This is in contrast to the findings of the NTP study, where male rats exposed to CDMA-modulated signals exhibited increased DNA damage in peripheral blood leukocytes and showed a statistically significant trend toward elevated DNA damage in the frontal cortex, hippocampus, and blood leukocytes. The micronucleus test was negative in all three studies.

What is largely consistent between the present studies and the NTP study, are the findings that suggest a potential metabolic impact of chronic, high-level RF-EMF exposure. In both cases, rats exposed to RF-EMF exhibited lower body weights, in part longer survival times, and less severe (NTP study) or less frequent (Japan/Korea studies) chronic progressive nephropathy (see table 1). In fact, the NTP study largely attributed the longer survival of RF-EMF-exposed animals to the less severe nephropathy.

In addition, the present studies recorded food intake of the animals. It was found that RF-EMF-exposed rats consistently consumed less food, within a range known to extend the lifespan of rodents [5, 6]. This reduced intake may largely explain the lower body weights, increased lifespan, and improved kidney health associated with RF-EMF exposure in the chronic bioassays discussed. Similar findings have been observed in studies on caloric restriction [5]. Rodents kept under conditions below the thermoneutral zone, as in the studies in question, expend a substantial amount of metabolic energy on maintaining body temperature. Thermal energy deposited in rodent bodies by RF-EMF exposure may reduce this metabolic requirement, thereby decreasing the number of calories needed to generate endogenous body heat from food [7], and thus providing a plausible explanation for the reduced food intake.

Taken together, neither the Japanese nor the Korean study indicates a carcinogenic or genotoxic effect of RF-EMF exposure at a wbSAR of 4 W/kg in male rats. However, due to the presumably limited statistical power of the individual studies, effects of exposure on the incidence of specific heart and brain tumours cannot be ruled out. The present studies provide additional insights on the metabolic impact of chronic, high-level RF-EMF exposures in male rats. As a general point, animal experiments with such high exposures serve to probe for a potential carcinogenic or genotoxic hazard and are not intended for the direct assessment of health risks to the general population. In addition, the whole-body exposure levels used are considerably higher than the EU-recommended limits for protecting the general public, and the results are only transferable to humans to a limited extent due to biological differences between humans and rodents (see also the NTP statement [8]).

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urn:nbn:de:0221-2026061660652

Spotlight - Jun/2026 no.1 (Eng)