

Radiofrequency Electromagnetic Fields: evaluation of cancer hazards

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IARC Monographs on physical agents

Monograph Volume 75 (2000)

Ionizing Radiation, Part I: X- and Gamma (γ)-Radiation, and Neutrons

Monograph Volume 78 (2001)

Ionizing Radiation, Part II: Some Internally Deposited Radionuclides

Monograph Volume 80 (2002)

Non-ionizing Radiation, Part I: Static and Extremely Low-Frequency (ELF) Electromagnetic Fields

Monograph Volume 102 (2011)

Non-ionizing Radiation, Part II, Radiofrequency Electromagnetic Fields (RF-EMF)

IARC Monograph on RF-EMF

In May 2011, an IARC Monographs Working Group evaluated the published scientific evidence with regards to the carcinogenic hazards from exposure to radiofrequency electromagnetic fields (RF-EMF). About 900 publications on RF-EMF and cancer were reviewed, covering

- exposure data
- epidemiology of human cancer
- cancer in experimental animals
- mechanistic and other relevant data

The Working Group considered three sources of exposure to RF-EMF:

- **environmental** sources
broadcast antennas, base stations, medical devices, smart meters, Wi-Fi
- **occupational** sources
high-frequency dielectric and induction heaters, radar installations
- **personal** devices
cordless telephones, mobile telephones (cell phones), *Bluetooth*

Exposure data

Sources of Radiofrequency Electromagnetic Fields ¹⁾

Source	Frequency	Exposure Level (mW/cm ²)	Distance	Time	Spatial features
Cell phone	900 MHz, 1800 MHz	1–5	At ear	During call	Highly localized
Cell-phone base station	900 MHz, 1800 MHz	0.000005–0.002	50 to a few thousand feet	Constant	Relatively uniform
Microwave oven	2450 MHz	~50 .05–0.2	2 inches 2 feet	During use	Localized, non-uniform
Local area networks (Wi-Fi)	2.4–5 GHz	0.0002–0.001 (wireless router)	3 feet	Constant when nearby	Localized, non-uniform
Radio/TV broadcast	Wide spectrum	0.001 (top 1% of the population)	Far from source (in most cases)	Constant	Relatively uniform
Smart meter	900 MHz, 2400 MHz	0.002–0.0002 (1 W, 5% duty cycle)	3–10 feet	When in proximity during transmission	Localized, non-uniform

1. EPRI, Electric Power Research Institute (2011) Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model

Exposures from a mobile telephone

Holding a mobile phone to the ear can result in high specific absorption-rate (SAR) values in the brain, depending on the position of the phone and its antenna, and the quality of the connection with the base-station.

For children – compared with adults – the average deposition of RF-energy from a mobile phone can be up to 2-fold higher in the brain and up to 10-fold higher in the bone marrow of the skull.

The use of hands-free kits lowers exposure to the brain to <10% of the value resulting from use at the ear.

Epidemiology

Occupational exposure to RF-EMF: some positive but inconsistent signals

	cases/controls	relative risk (95%CI)	
Thomas <i>et al.</i> 1987	435/386	1.7 (1.1–2.7)	Brain cancer
A death-certificate-based case-control study, with job title as proxy for RF-EMF exposure. Excess risk was attenuated when workers exposed to soldering fumes or lead were excluded: OR, 1.4 (0.7–3.1).			
Grayson <i>et al.</i> 1996	230/920	1.39 (1.01–1.90)	Brain cancer
A large case-control study among US Air Force personnel exposed to equipment producing RF-EMF. Exposure assessment relied on job title and time of deployment, cancer cases were taken from hospital discharge records, but were not confirmed.			

	cohort	relative risk (95%CI)	
Lagorio <i>et al.</i> 1997	682	5.0 (1.3–27.9)	Leukaemia/lymphoma
A mortality study among workers in a plastic-ware industry, with exposure to RF-EMF (during sealing), and to vinyl chloride monomer. The study is small, possible confounding is not addressed.			

Degrave <i>et al.</i> 2009	2932	7.2 (1.1–48.9)	Leukaemia/lymphoma
Cause-specific mortality study among Belgian soldiers in battalions equipped with radar. Follow-up problematic; co-exposure to ionizing radiation suggested			

Environmental exposure to RF-EMF: no solid data

Ecological and case-control studies have been carried out to investigate potential associations of brain cancer with RF emissions from transmission antennas. These studies are generally limited by reliance on measures of geographic proximity to the antennas as an exposure surrogate. Substantial exposure misclassification is unavoidable. For the same reason, no conclusions can be drawn from the limited data that were available on risk for leukaemia, lymphoma or a number of other cancers.

Personal exposure to RF-EMF: mobile telephone use

- Three types of study addressed the question of cancer risk and mobile-phone use
- **Ecological studies** on time trends of disease rates.
These analyses covered the period of the late 1990s and early 2000s, i.e. before mobile phone use became widespread.
- **Cohort study**
A total of 257 cases of glioma were found in 420,095 subscribers to two Danish telephone companies, with 253.9 expected. Having a subscription was taken as a surrogate for phone use. The study suffers from exposure misclassification.
- **Case-control studies:** Overall, these studies provide the strongest evidence to date.

Case-control studies on mobile phone use

Muscat *et al.* (2000), Inskip *et al.* (2001), and Auvinen *et al.* (2002) published early studies in the period of increasing use, with exposure assessment by self-reported history or by subscription records, and imprecise effect estimates.

	Phone type	Odds ratio (95%CI)	(from: Auvinen <i>et al.</i> , 2002)
Glioma (n=398)	all phones	1.5 (1.0–2.4)	
	digital phones	1.0 (0.5–2.0)	
	analog phones	2.1 (1.3–3.4)	(analog wireless phones emit more RF-energy)

INTERPHONE (Cardis *et al.*, 2010), a multicentre case-control study of mobile-phone use and brain tumours, including glioma, acoustic neuroma, and meningioma.

The pooled analysis included 2708 glioma cases and 2972 controls (2000–2004; participation rates 64% and 53%, resp.). Ever/never use of a mobile phone yielded an OR of 0.81 (0.70–0.94). Odds ratios were uniformly below or close to unity for all deciles of exposure except for the highest decile (cumulative call time, >1640 hrs): OR, 1.40 (1.03–1.89).

Studies from Sweden (pooled analysis, Hardell *et al.*, 2011)

The analysis included 1148 glioma cases (ascertained in 1997–2003) and 2438 controls obtained through cancer/population registries. Questionnaires and telephone interviews were used to obtain information on use of mobile and cordless phones (response rates 85% and 84%). Those who had used a phone for >1 year had an OR for glioma of 1.3 (95% CI 1.1–1.6), which increased with longer time since first use and with total call time, to 3.2 (2.0–5.1) for > 2000 hours of use.

Although both the INTERPHONE study and the Swedish studies are susceptible to bias, the Working Group concluded that the findings cannot be dismissed as reflecting bias alone, and that a causal interpretation is possible. A similar conclusion was drawn for acoustic neuroma, from these studies and from a Japanese study. For meningioma, parotid-gland tumours, leukaemia, lymphoma, and other cancers, the Working Group found the evidence insufficient to reach a conclusion.

The Working Group concluded: there is **limited evidence** in humans for the carcinogenicity of RF-EMF, based on positive associations between glioma and acoustic neuroma and exposure to RF-EMF from wireless telephones.

The Working Group reviewed more than 40 studies that assessed the carcinogenicity of RF-EMF in rodents. Exposures included 2450-MHz RF-EMF and various RF-EMF types that simulated emissions from mobile phones. Increased cancer incidences were noted in 2/12 studies with tumour-prone animals, in 1/18 studies with initiation-promotion protocols, and in 4/6 co-carcinogenesis studies after exposure to RF-EMF in combination with a known carcinogen.

The Working Group concluded that there is **limited evidence** in experimental animals for the carcinogenicity of RF-EMF.

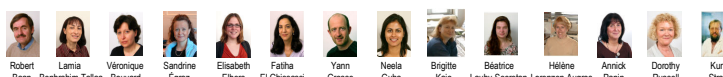
The Working Group reviewed many studies with endpoints relevant to mechanisms of carcinogenesis, including genotoxicity, effects on immune function, gene and protein expression, cell signalling, oxidative stress, apoptosis, effects on the blood-brain barrier, etc. There was evidence of an effect of RF-EMF on some of these endpoints, but the results provided only weak mechanistic evidence relevant to RF-EMF-induced cancer in humans.

Radiofrequency electromagnetic fields are **possibly carcinogenic to humans** (Group 2B)

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