



Cell Phone Radio Frequency Radiation Studies

Cell phones are used by 95% of American adults.¹ Given the large number of users, any harmful effects associated with cell phone use could be a significant public health concern.

Cell phones use radio frequency radiation (RFR) to transmit signals. The U.S. Food and Drug Administration (FDA) nominated RFR for study by the National Toxicology Program (NTP), due to widespread human exposure and limited information about the potential health effects of long-term use of cell phones.

What did NTP study?

NTP conducted toxicology studies in rats and mice to help clarify potential health hazards, including cancer risk, from exposure to RFR used in 2G and 3G cell phones. 2G and 3G networks were standard when the studies were designed and are still used for phone calls and texting.

The \$30 million NTP studies took more than 10 years to complete and are the most comprehensive assessment, to date, of health effects in animals exposed to RFR. The results will help guide other studies of newer technologies.

If you are concerned about potential health risks from RFR, the FDA suggests the following tips:²

- Use speaker mode or a headset to place more distance between your head and the cell phone.
- Reduce the amount of time spent using your cell phone.



What did the studies find?

NTP studies found that exposure to high levels of RFR, like that used in 2G and 3G cell phones, was associated with:

- **Clear evidence of tumors in the hearts of male rats.** The tumors were malignant schwannomas.
- **Some evidence of tumors in the brains of male rats.** The tumors were malignant gliomas.
- **Some evidence of tumors in the adrenal glands of male rats.** The tumors were pheochromocytomas.

For female rats, and male and female mice, it was unclear, also known as equivocal, whether cancers observed in the studies were associated with exposure to RFR.

The conclusions were based on the NTP four categories of evidence that a substance may cause cancer.

- Clear evidence (highest)
- Some evidence
- Equivocal evidence
- No evidence (lowest)



Do the rat and mouse findings apply to humans?

The findings in animals cannot be directly applied to humans for two key reasons:

- *The exposure levels and durations were greater than what people may receive from cell phones.*
- *The rats and mice received RFR across their whole bodies, which is different from the more localized exposures humans may receive, like from a cell phone in their pocket or next to their head.*

However, the studies question the long-held assumption that radio frequency radiation is of no concern as long as the energy level is low and does not significantly heat the tissues.

Still, the effects observed in the animals were relatively rare. NTP scientists are not sure why male rats appear to be at greater risk for developing tumors compared to female rats.

How do the RFR levels used in the studies compare to typical human exposures?

The lowest exposure level used in the studies was equal to the maximum local tissue exposure currently allowed for cell phone users. This power level rarely occurs with typical cell phone use. The highest exposure level in the studies was four times higher than the maximum power level permitted for local tissues.



Did NTP find health effects other than cancer?

NTP found lower body weights among newborn rats and their mothers, especially when exposed to high levels of RFR during pregnancy and lactation, yet these animals grew to normal size.

What factors contributed to the NTP conclusions?

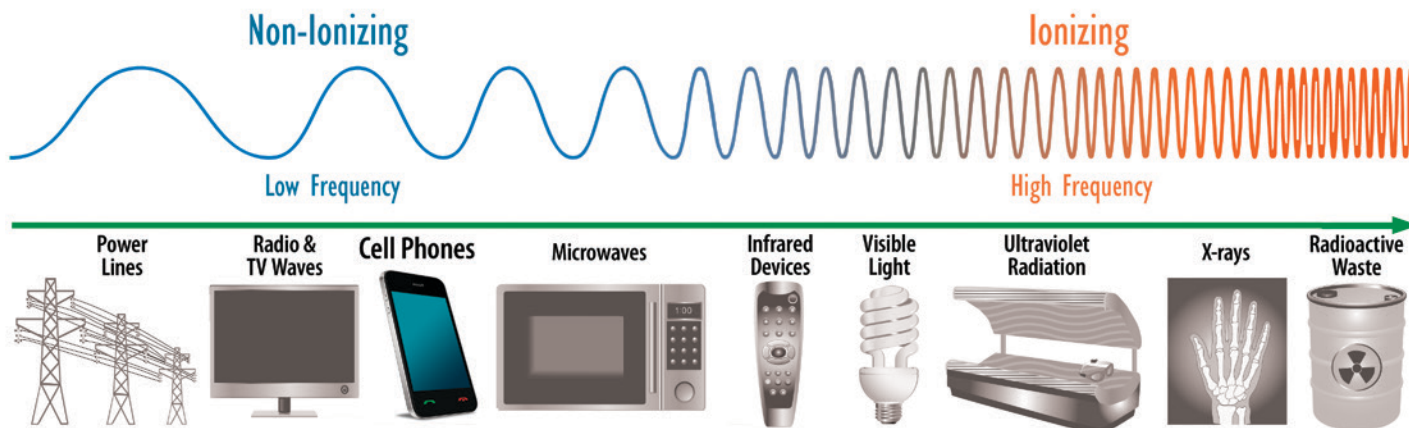
In addition to seeing tumors in the male rats with higher exposures to RFR, NTP scientists also observed other changes in the hearts of exposed male and female rats that supported their conclusions.

The evidence for tumors in the brain and adrenal glands was not as strong as what NTP scientists saw in the heart. However, the type of brain cancer observed is similar to a type of brain tumor linked to heavy cell phone use in some human studies.³

Why did NTP expose the animals' whole bodies to RFR?

Although many previous studies focused on exposure to the brain, NTP scientists wanted to make sure that they were considering health effects to the whole body, especially since many people do not hold their phones next to their head much of time.

Electromagnetic Spectrum



RFR used in cell phones is at the lower frequency and lower energy end of the electromagnetic spectrum.



What is the difference between electric and magnetic fields and RFR?

RFR is a subcategory of electric and magnetic fields (EMF), which are the invisible waves of force that surround any electrical device. The different types of EMF are distinguished by their frequencies. RFR is a form of low frequency, non-ionizing radiation that was thought to be relatively harmless.

How were the studies conducted?

Rats and mice were exposed to RFR in special chambers for up to two years, or most of their natural lives. NTP scientists looked for a range of cancers and noncancer health effects.

Exposure to RFR began in the womb for rats and at 5-6 weeks old for mice. The RFR exposure was intermittent, 10 minutes on and 10 minutes off, totaling about 9 hours each day. The RFR levels ranged from 1.5 to 6 watts per kilogram of body weight in rats, and 2.5 to 10 watts per kilogram in mice.

The chambers were shielded rooms with a transmitting antenna that radiated RFR fields, plus rotating stirrers that generated a uniform field.^{4,5} Pilot studies established field strengths that did not raise animal body temperatures excessively.⁶

The rats and mice were exposed to whole body RFR at frequencies of 900 and 1900 megahertz, respectively, from two technologies – Code Division Multiple Access (CDMA) and Global System for Mobile Communications (GSM).

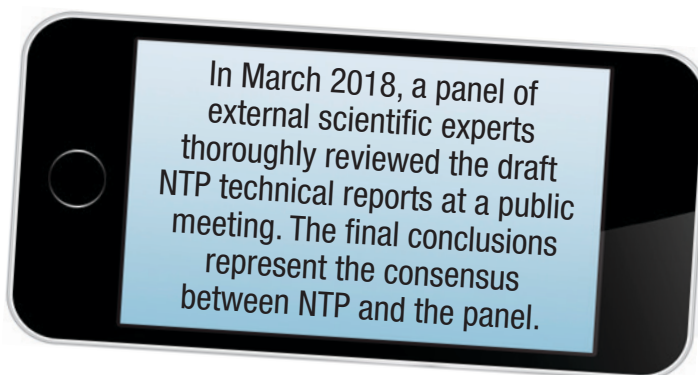
NTP and RFR experts from the National Institute of Standards and Technology (NIST) and the IT'IS Foundation designed and built the chambers specifically for these studies.



Chambers at the IIT Research Institute in Chicago where the studies took place

What is the difference between CDMA and GSM?

CDMA and GSM are two common ways of transmitting cell phone signals in the U.S. and Europe. There are substantial differences in signal structure that may result in different RFR exposures, so NTP wanted to expose the animals to both modulations.



How do the NTP studies relate to 4G, 5G, or Wi-Fi?

NTP studies of RFR used in 2G and 3G cell phones do not apply to 4G or 5G technologies. These newer technologies use different methods of signal modulation than NTP used in the studies. The NTP studies also did not investigate frequencies and modulations used for Wi-Fi.

What were the studies' strengths?

NTP was able to control exactly how much RFR the animals received — something that is not possible when studying human cell phone use.

Were there any surprise findings?

NTP found longer lifespans among the exposed male rats. This may be explained by an observed decrease in chronic kidney problems that are often the cause of death in older rats.

What will NTP do with the results of the studies?

NTP will provide these studies to the FDA and Federal Communications Commission. The agencies will review the information as they continue to monitor new research on the potential health effects of RFR.

Final reports and data tables are available on the NTP website at <https://ntp.niehs.nih.gov/go/cellphone>.



Are future studies planned?

NTP is collaborating with NIST and IT'IS to develop smaller RFR exposure chambers for additional short-term studies that will take weeks and months rather than years. These studies will focus on further clarifying what NTP learned in the long-term studies and investigating the possibility of DNA damage in exposed tissues.

The exposure system is also being designed so studies of different RFR frequencies and modulations can keep up with the changing technologies in the telecommunications industry.

NTP is also hoping to identify biomarkers of damage from RFR exposure. These would be measurable physical changes that can be seen in shorter periods of time than it takes to develop cancer. Examples could be changes in heart rate after exposure or molecular changes that might be predictive of cancer. If scientists can better understand biological changes in animals, they will know more about what to look for in humans.



Where can I go for more information?

For more information on what federal agencies are doing to determine whether RFR used in cell phones may affect human health, visit the following websites:

National Toxicology Program

<https://ntp.niehs.nih.gov/go/cellphone>

National Cancer Institute

www.cancer.gov/about-cancer/causes-prevention/risk/radiation/cell-phones-fact-sheet

U.S. Food and Drug Administration

<https://go.usa.gov/B5tx>

Federal Communications Commission

www.fcc.gov/consumers/guides/wireless-devices-and-health-concerns

The National Toxicology Program is an interagency program headquartered at the **National Institute of Environmental Health Sciences** that tests and evaluates chemicals in our environment.

For more information on NTP, go to <https://ntp.niehs.nih.gov>.

¹ Pew Research Center. 2018. Mobile Fact Sheet. Available: www.pewinternet.org/fact-sheet/mobile [accessed 24 October 2018].

² FDA (U.S. Food and Drug Administration). 2017. Reducing Exposure: Hands-free Kits and Other Accessories. Available: <https://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/CellPhones/ucm116293.htm> [accessed 30 October 2018].

³ IARC (International Agency for Research on Cancer). 2013. *Non-Ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields*. IARC Monogr Eval Carcinog Risks Hum 102:1-481.

⁴ Capstick MH, Kuehn S, Berdinas-Torres V, Gong Y, Wilson PF, Ladbury JM, Koepke G, McCormick DL, Gauger J, Melnick RL, Kuster N. 2017. A radio frequency radiation exposure system for rodents based on reverberation chambers. *IEEE T Electromagn C* 59(4):1041-1052.

⁵ Gong Y, Capstick MH, Kuehn S, Wilson PF, Ladbury JM, Koepke G, McCormick DL, Melnick RL, Kuster N. 2017. Life-time dosimetric assessment for mice and rats exposed in reverberation chambers for the two-year NTP cancer bioassay study on cell phone radiation. *IEEE T Electromagn C* 59(6):1798-1808.

⁶ Wyde ME, Horn TL, Capstick MH, Ladbury JM, Koepke G, Wilson PF, Kissling GE, Stout MD, Kuster N, Melnick RL, Gauger J, Bucher JR, McCormick DL. 2018. Effect of cell phone radiofrequency radiation on body temperature in rodents: Pilot studies of the National Toxicology Program's reverberation chamber exposure system. *Bioelectromagnetics* 39(3):190-199.



Cell Phones and Cancer Risk

Why is there concern that cell phones may cause cancer or other health problems?

There are three main reasons why people are concerned that cell phones (also known as “mobile” or “wireless” telephones) might have the potential to cause certain types of cancer or other health problems:

- Cell phones emit radiofrequency radiation (radio waves), a form of non-ionizing radiation, from their antennas. Parts of the body nearest to the antenna can absorb this energy.
- The number of cell phone users has increased rapidly. There were over 400 million cell phone subscribers in the United States in 2017, according to the [Cellular Telecommunications and Internet Association](#). Globally, there are [more than 5 billion cell phone users](#).
- Over time, the number of cell phone calls per day, the length of each call, and the amount of time people use cell phones have increased. Because of changes in cell phone technology and increases in the number of base stations for transmitting wireless signals, the exposure from cell phone use—power output—has changed, mostly lowered, in many regions of the United States ([1](#)).

The NCI fact sheet [Electromagnetic Fields and Cancer](#) includes information on wireless local area networks (commonly known as Wi-Fi), cell phone base stations, and cordless telephones.

What is radiofrequency radiation and how does it affect the human body?

Radiofrequency radiation is a form of electromagnetic radiation. Electromagnetic radiation can be categorized into two types: ionizing (e.g., x-rays, radon, and cosmic rays) and non-ionizing (e.g., radiofrequency and extremely low frequency, or power frequency). Electromagnetic radiation is defined according to its wavelength and frequency, which is the number of cycles of a wave that pass a reference point per second. Electromagnetic frequencies are described in units called hertz (Hz).

The energy of electromagnetic radiation is determined by its frequency; ionizing radiation is high frequency, and therefore high energy, whereas non-ionizing radiation is low frequency, and therefore low energy. The NCI fact sheet [Electromagnetic Fields and Cancer](#) lists sources of radiofrequency radiation. More information about ionizing radiation can be found on the [Radiation](#) page.

The frequency of radiofrequency electromagnetic radiation ranges from 30 kilohertz (30 kHz, or 30,000 Hz) to 300 gigahertz (300 GHz, or 300 billion Hz). Electromagnetic fields in the radiofrequency range are used for telecommunications applications, including cell phones, televisions, and radio transmissions. The human body absorbs energy from devices that emit radiofrequency electromagnetic radiation. The dose of the absorbed energy is estimated using a measure called the specific absorption rate (SAR), which is expressed in watts per kilogram of body weight.

Exposure to ionizing radiation, such as from x-rays, is known to increase the risk of cancer. However, although many studies have examined the potential health effects of non-ionizing radiation from radar,

microwave ovens, cell phones, and other sources, there is currently no consistent evidence that non-ionizing radiation increases cancer risk in humans (2).

The only consistently recognized biological effect of radiofrequency radiation in humans is heating. The ability of microwave ovens to heat food is one example of this effect of radiofrequency radiation. Radiofrequency exposure from cell phone use does cause heating to the area of the body where a cell phone or other device is held (e.g., the ear and head). However, it is not sufficient to measurably increase body temperature. There are no other clearly established effects on the human body from radiofrequency radiation.

How is radiofrequency radiation exposure measured in epidemiologic studies?

Epidemiologic studies use information from several sources, including questionnaires and data from cell phone service providers, to estimate radiofrequency radiation exposure. Direct measurements are not yet possible outside of a laboratory setting. Estimates take into account the following:

- How “regularly” study participants use cell phones (the number of calls per week or month)
- The age and the year when study participants first used a cell phone and the age and the year of last use (allows calculation of the duration of use and time since the start of use)
- The average number of cell phone calls per day, week, or month (frequency)
- The average length of a typical cell phone call
- The total hours of lifetime use, calculated from the length of typical call times, the frequency of use, and the duration of use

What has epidemiologic research shown about the association between cell phone use and cancer risk?

Researchers have carried out several types of epidemiologic studies in humans to investigate the possibility of a relationship between cell phone use and the risk of malignant (cancerous) brain tumors, such as gliomas, as well as benign (noncancerous) tumors, such as acoustic neuroma (tumors in the cells of the nerve responsible for hearing that are also known as vestibular schwannomas), meningiomas (usually benign tumors in the membranes that cover and protect the brain and spinal cord), and parotid gland tumors (tumors in the salivary glands) (3).

In one type of study, called a case-control study, cell phone use is compared between people with these types of tumors and people without them. In another type of study, called a cohort study, a large group of people who do not have cancer at study entry is followed over time and the rate of these tumors in people who did and didn't use cell phones is compared. Cancer incidence data can also be analyzed over time to see if the rates of brain tumors changed in large populations during the time that cell phone use increased dramatically. These studies have not shown clear evidence of a relationship between cell phone use and cancer. However, researchers have reported some statistically significant associations for certain subgroups of people.

Three large epidemiologic studies have examined the possible association between cell phone use and cancer: Interphone, a case-control study; the Danish Study, a cohort study; and the Million Women Study, another cohort study.

Interphone

How the study was done: This is the largest health-related case-control study of cell phone use and the risk of head and neck tumors. It was conducted by a consortium of researchers from 13 countries. The data came from questionnaires that were completed by study participants.

What the study showed: Most published analyses from this study have shown no statistically significant increases in brain or central nervous system cancers related to higher amounts of cell phone use. One analysis showed a statistically significant, although modest, increase in the risk of glioma among the small proportion of study participants who spent the most total time on cell phone calls. However, the researchers considered this finding inconclusive because they felt that the amount of use reported by some respondents was unlikely and because the participants who reported lower levels of use appeared to have a slightly reduced risk of brain cancer compared with people who did not use cell phones regularly (4–6).

An analysis of data from all 13 countries participating in the Interphone study reported a statistically significant association between intracranial distribution of tumors within the brain and self-reported location of the phone (7). However, the authors of this study noted that it is not possible to draw firm conclusions about cause and effect based on their findings.

Additional analyses of data from Interphone countries

An analysis of data from five Northern European countries in the Interphone study showed an increased risk of acoustic neuroma only in those who had used a cell phone for 10 or more years (8).

In subsequent analyses of Interphone data, investigators addressed issues of risk according to specific location of the tumor and estimated exposures. One analysis of data from seven of the countries in the Interphone study found no relationship between brain tumor location and regions of the brain that were exposed to the highest level of radiofrequency radiation from cell phones (9). However, another study, using data from five of the countries, reported suggestions of an increased risk of glioma and, to a lesser extent, of meningioma developing in areas of the brain experiencing the highest exposure (10).

Danish Study

How the study was done: This cohort study, conducted in Denmark, linked billing information from more than 358,000 cell phone subscribers with brain tumor incidence data from the Danish Cancer Registry.

What the study showed: No association was observed between cell phone use and the incidence of glioma, meningioma, or acoustic neuroma, even among people who had been cell phone subscribers for 13 or more years (11–13).

Million Women Study

How the study was done: This prospective cohort study conducted in the United Kingdom used data obtained from questionnaires that were completed by study participants.

What the study showed: Self-reported cell phone use was not associated with an increased risk of glioma, meningioma, or non-central nervous system tumors. Although the original published findings reported an association with an increased risk of acoustic neuroma (14), this association disappeared after additional years of follow-up of the cohort (15).

In addition to these three large studies, other, smaller epidemiologic studies have looked for associations between cell phone use and cancer. These include:

- Two NCI-sponsored case-control studies, each conducted in multiple U.S. academic medical centers or hospitals between 1994 and 1998 that used data from questionnaires (16) or computer-assisted personal interviews (17). Neither study showed a relationship between cell phone use and the risk of glioma, meningioma, or acoustic neuroma.
- The Cerenat study, another case-control study conducted in multiple areas in France from 2004 to 2006 using data collected in face-to-face interviews using standardized questionnaires (18). This study found no association for either gliomas or meningiomas when comparing regular cell phone users with non-users. However, the heaviest users had significantly increased risks of both gliomas and meningiomas.
- A pooled analysis of two case-control studies conducted in Sweden that reported statistically significant trends of increasing brain cancer risk for the total amount of cell phone use and the years of use among people who began using cell phones before age 20 (19).
- Another case-control study in Sweden, part of the Interphone pooled studies, did not find an increased risk of brain cancer among long-term cell phone users between the ages of 20 and 69 (20).
- The CEFALO study, an international case-control study of children diagnosed with brain cancer between ages 7 and 19, which found no relationship between their cell phone use and risk for brain cancer (21).

Investigators have also conducted analyses of incidence trends to determine whether the incidence of brain or other cancers has changed during the time that cell phone use increased dramatically. These include:

- An analysis of data from NCI's [Surveillance, Epidemiology, and End Results \(SEER\) Program](#) evaluated trends in cancer incidence in the United States. This analysis found no increase in the incidence of brain or other central nervous system cancers between 1992 and 2006, despite the dramatic increase in cell phone use in this country during that time (22).
- An analysis of incidence data from Denmark, Finland, Norway, and Sweden for the period 1974–2008 similarly revealed no increase in age-adjusted incidence of brain tumors (23).
- A series of studies testing different scenarios (called simulations by the study authors) were carried out using incidence data from the Nordic countries to determine the likelihood of detecting various levels of risk as reported in studies of cell phone use and brain tumors between 1979 and 2008. The results were compatible with no increased risks from cell phones, as reported by most epidemiologic studies. The findings did suggest that the increase reported among the subset of heaviest regular users in the Interphone study could not be ruled out but was unlikely. The highly increased risks reported in the Swedish pooled analysis were strongly inconsistent with the observed glioma rates in the Nordic countries (24).
- A 2012 study by NCI researchers (25) compared observed glioma incidence rates in U.S. SEER data with rates simulated from the small risks reported in the Interphone study (6) and the greatly increased risk of brain cancer among cell phone users reported in the Swedish pooled analysis (19). The authors concluded that overall, the incidence rates of glioma in the United States did not increase over the study period. They noted that the US rates could be consistent with the small increased risk seen among the subset of heaviest users in the Interphone study. The observed incidence trends were inconsistent with the high risks reported in the Swedish pooled study. These findings suggest that the increased risks observed in the Swedish study are not reflected in U.S. incidence trends.
- An analysis of primary brain tumor incidence data (including some of the first [benign brain and central nervous system tumor data](#) that SEER began collecting in 2004) reported that the incidence of acoustic neuromas (also known as vestibular schwannomas) was stable (unchanged) from 2004 to 2010.

What are the findings from experimental studies?

In 2011, two small studies were published that examined brain glucose metabolism in people after they had used cell phones. The results were inconsistent; whereas one study showed increased glucose metabolism in the region of the brain close to the antenna compared with tissues on the opposite side of the brain (26), the other study (27) found reduced glucose metabolism on the side of the brain where the phone was used.

The authors of these studies noted that the results were preliminary and that possible health outcomes from changes in glucose metabolism in humans were unknown. Such inconsistent findings are not uncommon in experimental studies of the biological effects of radiofrequency electromagnetic radiation in people (4). Some factors that can contribute to inconsistencies across such studies include assumptions used to estimate doses, failure to consider temperature effects, and lack of blinding of investigators to exposure status.

Another study investigated the flow of blood in the brain of people exposed to the radiofrequency radiation from cell phones and found no evidence of an effect on blood flow in the brain (28).

Early studies involving laboratory animals showed no evidence that radiofrequency radiation increased cancer risk or enhanced the cancer-causing effects of known chemical carcinogens (29–32).

Because of inconsistent findings from epidemiologic studies in humans and the lack of clear data from previous experimental studies in animals, in 1999 the Food and Drug Administration nominated radiofrequency radiation exposure associated with cell phone exposures for study in animal models by the U.S. National Toxicology Program (NTP), an interagency program that coordinates toxicology research and testing across the U.S. Department of Health and Human Services and is headquartered at the National Institute of Environmental Health Sciences, part of NIH.

The NTP [studied](#) radiofrequency radiation (2G and 3G frequencies) in rats and mice (33, 34). This large project was conducted in highly specialized labs that specified and controlled sources of radiation and measured their effects. The rodents experienced whole-body exposures of 3, 6, or 9 watts per kilogram of body weight for 5 or 7 days per week for 18 hours per day in cycles of 10 minutes on, 10 minutes off. A [research overview of the rodent studies](#), with links to the peer-review summary, is available on NTP website. The primary outcomes observed were a small number of cancers of Schwann cells in the heart and non-cancerous changes (hyperplasia) in the same tissues for male rats, but not female rats, nor in mice overall.

These experimental findings raise new questions as to the potential for radiofrequency radiation to result in cellular changes and offer potential avenues for further laboratory studies. Cancers in the heart are extremely rare in humans, where the primary outcomes of potential concern with respect to radiofrequency radiation exposure from cell phones are tumors in the brain and central nervous system. Schwann cells of the heart in rodents are similar to the kind of cells in humans that give rise to acoustic neuromas (also known as vestibular schwannomas), which some studies have suggested are increased in people who reported the heaviest use of cell phones. The NTP has stated that they will continue to study this exposure in animal models to further advance our understanding of the biological underpinnings of the effects reported above.

Another animal study, in which rats were exposed 7 days per week for 19 hours per day to radiofrequency radiation at 0.001, 0.03, and 0.1 watts per kilogram of body weight was reported by investigators at the Italian Ramazzini Institute (35). Among the rats with the highest exposure levels, the researchers noted an increase in heart schwannomas in male rats and non-malignant Schwann cell growth in the heart in male and female rats. However, key details necessary for interpretation of the results were missing: exposure methods, other standard operating procedures, and nutritional/feeding aspects. The gaps in the report from the study raise questions that have not been resolved.

Why are the findings from different studies of cell phone use and cancer risk inconsistent?

A few studies have shown some evidence of statistical association of cell phone use and brain tumor risks in humans, but most studies have found no association. Reasons for these discrepancies include the following:

- **Recall bias**, which can occur when data about prior habits and exposures are collected from study participants using questionnaires administered after diagnosis of a disease in some of the participants. It is possible that study participants who have brain tumors may remember their cell phone use differently from individuals without brain tumors. Many epidemiologic studies of cell phone use and brain cancer risk lack verifiable data about the total amount of cell phone use over time. In addition, people who develop a brain tumor may have a tendency to recall cell phone use mostly on the same side of the head where their tumor was found, regardless of whether they actually used their phone on that side of the head a lot or only a little.
- **Inaccurate reporting**, which can happen when people say that something has happened more or less often than it actually did. People may not remember how much they used cell phones in a given time period.
- **Morbidity and mortality** among study participants who have brain cancer. Gliomas are particularly difficult to study, for example, because of their high death rate and the short survival of people who develop these tumors. Patients who survive initial treatment are often impaired, which may affect their responses to questions. Furthermore, for people who have died, next-of-kin are often less familiar with the cell phone use patterns of their deceased family member and may not accurately describe their patterns of use to an interviewer.
- **Participation bias**, which can happen when people who are diagnosed with brain tumors are more likely than healthy people (known as controls) to enroll in a research study. Also, controls who did not or rarely used cell phones were less likely to participate in the Interphone study than controls who used cell phones regularly. For example, the Interphone study reported participation rates of 78% for meningioma patients (range among the individual studies 56–92%), 64% for glioma patients (range 36–92%), and 53% for control subjects (range 42–74%) (6).
- **Changing technology and methods of use.** Older studies evaluated radiofrequency radiation exposure from analog cell phones. Today, cell phones use digital technology, which operates at a different frequency and a lower power level than analog phones. Digital cell phones have been in use for more than two decades in the United States, and cellular technology continues to change (3). Texting and other applications, for example, are common uses of cell phones that do not require bringing the phone close to the head. Furthermore, [the use of hands-free technology, such as wired and wireless headsets, is increasing](#) and may reduce exposure by distancing the phone from the body (36, 37).

What are other possible health effects from cell phone use?

A broad range of health effects have been reported with cell phone use. Neurologic effects are of particular concern in young persons since the brain is the primary exposed organ. However, studies of memory, learning, and cognitive function have generally produced inconsistent results (38–41).

The most consistent health risk associated with cell phone use is distracted driving and vehicle accidents (42, 43).

What have expert organizations said about the cancer risk from cell phone use?

In 2011, the [International Agency for Research on Cancer](#) (IARC), a component of the World Health Organization, appointed an expert Working Group to review all available evidence on the use of cell phones. The Working Group classified cell phone use as “possibly carcinogenic to humans,” based on limited evidence from human studies, limited evidence from studies of radiofrequency radiation and cancer in rodents, and inconsistent evidence from mechanistic studies (4).

The Working Group indicated that, although the human studies were susceptible to bias, the findings could not be dismissed as reflecting bias alone, and that a causal interpretation could not be excluded. The Working Group noted that any interpretation of the evidence should also consider that the observed associations could reflect chance, bias, or confounding rather than an underlying causal effect. In addition, the Working Group stated that the investigation of risk of cancer of the brain associated with cell phone use poses complex methodologic challenges in the conduct of the research and in the analysis and interpretation of findings.

In 2011, the [American Cancer Society](#) (ACS) stated that the IARC classification means that there could be some cancer risk associated with radiofrequency radiation, but the evidence is not strong enough to be considered causal and needs to be investigated further. Individuals who are concerned about radiofrequency radiation exposure can limit their exposure, including using an ear piece and limiting cell phone use, particularly among children.

In 2018, the [ACS issued a statement on the draft NTP reports](#) noting that the findings were still inconclusive, and that, so far, a higher cancer risk in people has not been seen, but that people who are concerned should wear an earpiece when using a cell phone.

The [National Institute of Environmental Health Sciences](#) (NIEHS) states that the weight of the current scientific evidence has not conclusively linked cell phone use with any adverse health problems, but more research is needed.

The [U.S. Food and Drug Administration](#) (FDA) notes that studies reporting biological changes associated with radiofrequency radiation have failed to be replicated and that the majority of human epidemiologic studies have failed to show a relationship between exposure to radiofrequency radiation from cell phones and health problems. The FDA, which originally nominated this exposure for review by the NTP in 1999, [issued a statement on the draft NTP reports](#) released in February 2018, saying “based on this current information, we believe the current safety limits for cell phones are acceptable for protecting the public health.” FDA and the Federal Communications Commission share responsibility for regulating cell phone technologies.

The [U.S. Centers for Disease Control and Prevention](#) (CDC) states that no scientific evidence definitively answers whether cell phone use causes cancer.

The [Federal Communications Commission](#) (FCC) concludes that currently no scientific evidence establishes a definite link between wireless device use and cancer or other illnesses.

In 2015, the European Commission Scientific Committee on Emerging and Newly Identified Health Risks concluded that, overall, the epidemiologic studies on cell phone radiofrequency electromagnetic radiation exposure do not show an increased risk of brain tumors or of other cancers of the head and neck region (2). The Committee also stated that epidemiologic studies do not indicate increased risk for other malignant diseases, including childhood cancer (2).

What studies are under way that will help further our understanding of the possible health effects of cell phone use?

A large prospective cohort study of cell phone use and its possible long-term health effects was launched in Europe in March 2010. This study, known as [COSMOS](#), has enrolled approximately 290,000 cell phone users aged 18 years or older to date and will follow them for 20 to 30 years ([44](#), [45](#)).

Participants in COSMOS will complete a questionnaire about their health, lifestyle, and current and past cell phone use. This information will be supplemented with information from health records and cell phone records.

The challenge of this ambitious study is to continue following the participants for a range of health effects over many decades. Researchers will need to determine whether participants who leave the study are somehow different from those who remain throughout the follow-up period.

Although recall bias is minimized in studies such as COSMOS that link participants to their cell phone records, such studies face other problems. For example, it is impossible to know who is using the listed cell phone or whether that individual also places calls using other cell phones. To a lesser extent, it is not clear whether multiple users of a single phone, for example family members who may share a device, will be represented on a single phone company account. Additionally, for many long-term cohort studies, participation tends to decline over time.

Has radiofrequency radiation from cell phone use been associated with cancer risk in children?

There are theoretical considerations as to why the possible risk should be investigated separately in children. Their nervous systems are still developing and, therefore, more vulnerable to factors that may cause cancer. Their heads are smaller than those of adults and consequently have a greater proportional exposure to the field of radiofrequency radiation that is emitted by cell phones. And, children have the potential of accumulating more years of cell phone exposure than adults do.

Thus far, the data from studies in children with cancer do not support this theory. The first published analysis came from a large case-control study called CEFALO, which was conducted in Denmark, Sweden, Norway, and Switzerland. The study included children who were diagnosed with brain tumors between 2004 and 2008, when their ages ranged from 7 to 19 years. Researchers did not find an association between cell phone use and brain tumor risk either by time since initiation of use, amount of use, or by the location of the tumor ([21](#)).

Several studies that will provide more information are under way. Researchers from the Centre for Research in Environmental Epidemiology in Spain are conducting another international case-control study—[Mobi-Kids](#)—that will include 2000 young people (aged 10–24 years) with newly diagnosed brain tumors and 4000 healthy young people. The goal of the study is to learn more about risk factors for childhood brain tumors.

What can cell phone users do to reduce their exposure to radiofrequency radiation?

The FDA has suggested some steps that concerned cell phone users can take to reduce their exposure to radiofrequency radiation ([46](#)):

- Reserve the use of cell phones for shorter conversations or for times when a landline phone is not available.
- Use a device with hands-free technology, such as wired headsets, which place more distance between the phone and the head of the user.

Hands-free kits reduce the amount of radiofrequency radiation exposure to the head because the antenna, which is the source of energy, is not placed against the head (37). Exposures decline dramatically when cell phones are used hands-free.

Where can I find more information about radiofrequency radiation from my cell phone?

The FCC provides information about the specific absorption rate (SAR) of cell phones produced and marketed within the last 1 to 2 years. The SAR corresponds with the relative amount of radiofrequency radiation absorbed by the head of a cell phone user (47). Consumers can access this information using the phone's FCC ID number, which is usually located on the case of the phone, and the FCC's [ID search form](#).

How common is brain cancer? Has the incidence of brain cancer changed over time?

Brain cancer incidence and mortality (death) rates have changed little in the past decade.

In the United States, 23,880 new diagnoses and 16,830 deaths from brain and other central nervous system cancers are estimated for 2018 (48).

There is great variability in survival by brain tumor subtype, and by age at diagnosis. Overall, the 5-year relative survival for brain cancers diagnosed from 2008 through 2014 was 33.2% (49). This is the percentage of people diagnosed with brain cancer who will still be alive 5 years after diagnosis compared with the survival of a person of the same age and sex who does not have cancer.

The risk of developing brain cancer increases with age. From 2011 through 2015, there were fewer than 4.5 brain cancer cases for every 100,000 people in the United States under age 65, compared with approximately 19.1 cases for every 100,000 people in the United States who were ages 65 or older (49).

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Reviewed: November 1, 2018

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